Progress Review

Research and Development Projects

2020

National Aquatic Resources Research and Development Agency

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1 Fishing Technology Division

1.1 Study of flotsam associated fishery in offshore to Introduce management strategies for sustainable fishery

Flotsam associate fishery is one of main fishing operation conducting in Sri Lanka using Ring net; a kind of small-scale encircling net. This fishing techniques mainly associated with floating objects in the sea. Main target species of this fishing method is Main target species of this fishing method are *Decapterus russelli* (Indian scad), *Elagatis bipinulata* (Rainbow runner), *Canthidermis maculata* (rough triggerfish or spotted oceanic triggerfish). They collect various sizes Bigeye tuna, Yellowfin tuna, and Skipjack tuna as by-catch. Most of tuna family fish are in under size and immature fish. This fishing method is highly efficient method and fisherman are very attractive for this method day by day, they collect all fish who caught in the net. Therefore, objectives of the project were, Inquire the current situation of flotsam associated Ring net fishery and provide management strategies for future plans, disseminating the findings to the stakeholders, disseminating the findings to the Ministry of fisheries for policy making. This project was conducted based on catch data and boat log sheet data. Catch data were collected from Beruwala, Galle, and Tangalle and Kudawella fishey harbors. Length frequencies of Skipjack tune, Yellowfin tuna, Indian scad, Rainbow runner, rough triggerfish or spotted oceanic triggerfish were taken. 24-26cm length class was the highest number of fish recorded length class of Skip jack Tuna. They collect around 23% of Tuna in 24-26cm length class out of total tuna catch. In the case of Yellowfin tuna, highest frequency recorded length was 26-28cm and it was 24% while ring net fisherman collect 26% of Big eye tuna in 24-26 length class. All these length classes fish are immature and under size fish. Therefore, continuing of ring net fishing activities in present conditions, it will be a severe issue in Sri Lanka fisheries. During year 2020 ring net fisherman have caught 50550 metric tons of fish harvest. Among that 43500mts have collected from within the EEZ and rest have collected from beyond the EEZ. While total catch of the gill net was 12480 mt tons and catch of long line was 21290. Therefore, few recommendations were build according to the results obtained. As Fishing vessels with inboard engines up to the length of 18.3 meters (60 ft.) shall engage in ring net fishing operations within Sri Lankan waters, outside hundred nautical miles (100) or one hundred and fifteen miles (115) i.e. one hundred and eighty-five decimals two kilometers (185.2) from the shore and Fishing vessels with inboard engines exceeding 18.3 meters (60 ft.) and up to 24 meters (78.7 ft.) in length shall engage in ring net fishing operations within Sri Lankan waters, outside one Hundred and fifty nautical miles (150) or one hundred and seventy two decimal six miles (172.6) i.e. two hundred and seventy seven decimal eight kilometers (277.8) from the shore.

Financial Allocation (Rs): 1,900,000.00

Financial progress (%): 90 Physical Progress (%): 95

1.2 Study the fishing efficiency of Monofilament nets comparison with Nylon nets used in inland reservoirs in Sri Lanka.

Sri Lanka is endowed with more than 12,000 perennial and seasonal, reservoirs, covering the extent of about 260,000 ha of the country. These tanks are classified into major, medium, minor and micro tanks depending on their water spread (water surface area of a tank) and command area. Reservoir fishery helps significantly to increases the availability of fresh fish to the rural communities, enhanced livelihood opportunities and income for fishers and strengthening the rural economy. In Sri Lanka, the reservoir fishery is almost exclusively a gill-net fishery, while the pol and line fishery is very few. The permissible mesh size is over 3½ inches or over (knot to knot).Mostly, the gill-net fishing is carried out through the night. The nets are hauled during the dawn and fishermen return to one or more landing sites in a reservoir. Use of motorized boats for fishing, is strictly prohibited in Sri Lankan reservoirs. Similarly, seining and use of undersized meshed gill-nets are also banned. The bottom terrain as well

as numerous obstacles, such as submerged vegetation, prevent the use of any dragging gear. In order to the act no 02 in 1996, use of mono filament nets are prohibited in inland reservoirs due to its high catching efficiency. However, any scientific study has not been conducted, regarding the banned of mono filament net in inland reservoirs. There is a request, which come from the fishermen in inland reservoirs in Sri Lanka, to re-consider the ordinance, against to the Monofilament nets. Therefore, with the request of National Aquaculture Development Agency, a research was conducted to determine the fishing efficiency of monofilament nets comparatively to the nylon nets, in the inland reservoirs of Sri Lanka. Followings were the objectives of the projected which conducted as check the fishing efficiency of mono filament net and nylon net; determine the optimum mesh size of monofilament net, for fishing in inland reservoirs in Sri Lanka. In the initial stage, it was decided to select two pilot areas from north central and southern province of Sri Lanka, to carry out the project activities.

According to that, three perennial reservoirs from Anuradhapura district and, three perennial reservoirs from Hambantota district were selected, considering the scale of the reservoirs, i.e. large, intermediate and small scale. Huruluwewa, Aluthdiwulwewa and Manankattiyawewa reservoirs from the Anuradahapura district, and Ridiyagamawewa, Muruthawelawewa and Kattakaduwawewa, reservoirs from the Hambantota district were selected according to the desired scales respectively. NAQDA was agreed to provide all required fishing nets, however, required amount of net materials not received on time. It may due to, monofilament nets are not available in the local market of Sri Lanka. Due to the lack of raw materials, NARA decided to conduct the research works, only in southern province. The research was conducted in selected reservoirs of Southern province, as Muruthawela, Ridiyagama andKattakaduwa reservoir (Map 01). According to the convention of the bilateral talks, the mesh sizes was decided, for the research, under three sizes as, 3 ½ inch, (3 ½"), 4 ½ inch (4 ½") and 5 inch (5").The net mending work was assigned to the Community based fisheries organizations (CBFOs) of the selected reservoirs. The CBFOs was given the net mending materials from the NARA. The experimental trial fishing activities were conducted among the three reservoirs, since February in year 2020. Minimum two times (two days) or maximum three times (three days) per a month, the experimental trial fishing was conducted on a one reservoir. The experimental trial fishing activity was started on 14th February in 2020, and ended on 19th December in 2020, completing 33 fishing efforts during seven months, within all three reservoirs. As the result of it, 15 number of fish species, could be identified among the three reservoirs. The total catch by using both nylon and monofilament nets, among all three reservoirs was 410.6 Kg. Out of total catch, 54.43% by using monofilament nets, while 45.56% of fish had been caught by using nylon nets. According to the total harvest collected from monofilament nets, 83.09% of fish harvest has been collected from 5 inch mesh size monofilament nets. According to the research for the efficiency& ecofriendly fishing and avoid catching of immature, juvenile fish , monofilament nets, mesh size with 5inch, can be recommended for the use for fishery in inland reservoirs, especially in water deficient period. It will help to sustainable utilization of reservoir fishery.

Financial Allocation (Rs): 1,010,000.00

Financial progress (%): 98 Physical Progress (%): 95

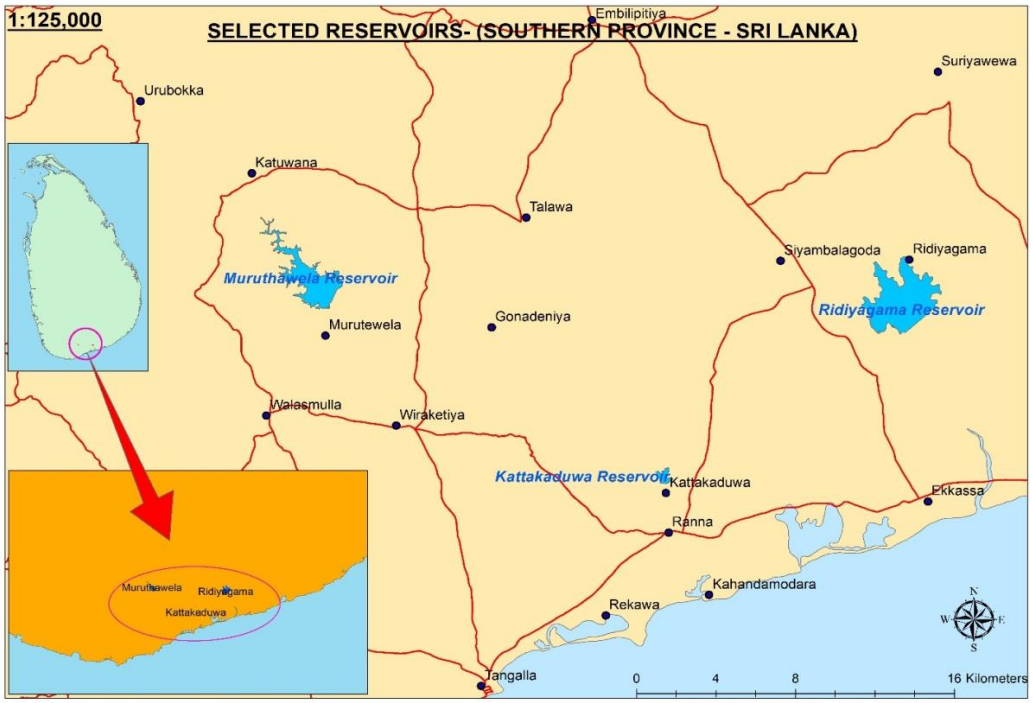


Figure 1.2-1 Location of selected reservoirs in Southern province of Sri Lanka

1.3 Deployment of submerged Fish Aggregating/Enhancing Devices and bottom set structures for fish habitat enhancement in coastal waters.

Deployment of low cost fishing Aggregating Devices is a popular fishing technique in many countries of the Asian region. Even in Sri Lanka these low cost FADs are used quite successfully in the western and southern areas and sees this as having good potential whereby the small scale fishers in the other parts of the country can earn good incomes.

Primary users of Fish Aggregating Devices in this coastal region are artisanal fishermen who, without major improvements of their tools of production (fishing gear, boats) are capable of obtaining better catches than from traditional grounds or to complement their normal landings from fish caught adjacent to FADs. Improved fish landings, besides having a direct impact on the availability of fish on the market, improve the socio-economic status of artisanal fishermen in the community through increased income.

Objectives

- Introducing new fishing technologies for low cost fish aggregating devises (FADs), Floating Buoy and Fish Enhancing Devices (FEDs) to enhance the living standards and socio economic aspect among small scale fishing community in coastal zone of Sri Lanka.

- To increase the fish production of coastal and offshore areas.
- To increase the income of fishers.
- To supply good quality fresh fish for consumption.
- Disseminating the findings to the stakeholders.
- Disseminating the findings to the Ministry of fisheries for policy making.

Scope

- Popularize the FAD, Buoys and FED associated fishery among the small scale fishing community.

Select suitable sites, location around the coastal zone in Sri Lanka. Implementation and deployment of FADs & FED's will be carryout with the help of fishing community participation.

Description	Total (Rs Mn)
Purchasing of materials	0.8
Constructions Fishing gear	0.07
OT/Sub/Holiday pay	0.35
Fuel for land vehicle	0.14
Boat hire and diver charges	0.25
accommodation	0.15
Operational expenses	0.15
monitoring	0.09
Total	2

Expected Outcome

- Sound scientific regulatory measures and environmentally friendly efficient fishing methods for coastal fishery to enhance fish production.
- To provide breeding grounds, shelters and nursery grounds for the juveniles.
- To enhance the living standards and socio-economic aspect among lobster fishing community in coastal zone of Sri Lanka.

The project was discontinued in the month of June 2020 as the expected deployment of FEDs and FADs in Gallle due to lock down on covid pandemic situation and the onset of monsoon. Results and recommendations of previous studies on the same had been undertake by the Department of Fisheries and Aquatic resources to deploy discarded fishing boats and buses in Galle and Trincomalee.

Financial Allocation (Rs): 110,000.00

Financial progress (%): 91 Physical Progress (%): 0

2 Marine Biological Resources Division

2.1 Monitoring and Assessment of Pelagic (small pelagic and large pelagic) and non-fin fish fishery resources (sea cucumber and lobsters) using port sampling

Large Pelagic Fishery

Port sampling and fisheries statistics

Large Pelagic Port Sampling is a collaborative fisheries data collection program implemented by the Marine Biological Resources Division (MBRD) of NARA, Department of Fisheries and Aquatic Resources (DFAR), and Statistics Unit of Ministry of Fisheries (MoF) for obtaining large pelagic fish landing data. Large pelagic resources mainly comprise of tuna and tuna-like species. The large pelagic port sampling survey in Sri Lanka was started in the 1990s by NARA. The survey's main objective was to obtain catch and effort data on large pelagic fish, particularly tuna and tuna-like fish. Further, the port sampling data collection program is being developed under working package II of the Norway-Sri Lanka bi-lateral project. Consequently, manual data collection forms will gradually be substituted with electronic data collection procedures.

IOTC data submission and attending working parties organized by IOTC

It is mandatory to submit large pelagic fisheries data to the Indian Ocean Tuna Commission (IOTC). The data collected annually via the port sampling program must be analyzed and submitted to the IOTC before 30th June. The data submitting to IOTC needs to comply with the relevant resolutions implemented by IOTC. In the submission, catch data, effort data, length-frequency data, information on discards, and vessel information are provided in detail as per those resolutions' requirements. As a result of complying with the resolutions relating to data submission, Sri Lanka achieved a 90 % overall compliance rate in 2019. It is a 7 % increase as compared to the previous year, 2018. This is a substantial achievement compared to our past compliance rates and compliance records of other coastal states in the Indian Ocean.

IOTC organizes and conducts working party meetings annually. The working parties generally consist of scientists attending in their individual capacity. The working party meetings are open to scientists interested in the relevant issues under the working party's consideration. The working party's most common objective is to provide the IOTC Scientific Committee with the analyses of the current status of the relevant fish stocks and an evaluation of possible management actions. Some Working Parties are established to analyze and produce recommendations on a specific technical problem. Due to the unexpected conditions that occurred in 2020 due to COVID-19, the following working party meetings were virtually conducted. An information paper titled, Neritic tuna fishery in Sri Lankan waters: An update, was submitted to the Working Party on Neritic Tuna.

- 10th Working Party on Neritic Tuna (WPNT 10) - (06/07/2020 - 08/07/2020)
- 18th Working Party on Billfish (WPB 18) - (02/09/2020 to 04/09/2020).
- 16th Working Party on Ecosystems and Bycatch (WPEB16) - (07/09/2020 - 10/09/2020)
- 22nd Working Party on Tropical Tuna (WPTT22): Stock Assessment Meeting - (19/10/2020 - 23/10/202)
- 15th Working Party on Data Collection and Statistics (WPDCS15) - (30/11/2020-03/12/2020)

Small Pelagic Fishery

The small pelagic group represents over seventy-five marine species found in Sri Lankan waters. The key target species in the fishery includes sardines, herrings, anchovies and mackerels. The fishery is conducted by Outboard Engine Fiber Reinforced Plastic (OFRP) boats, motorized and non-motorized

traditional crafts. The main gear used in the fishery is small mesh gillnets. Surrounding nets are also used in some districts. In addition, the beach seine, a traditional fishing gear operating seasonally in Sri Lanka, also catches a considerable quantity of small pelagic.

MBRD continued to conduct the port sampling data collection programme in 2020 despite the COVID-19 pandemic situation at major small pelagic fish landing sites with the key objective of studying the trends in the fishery analyzing the data for various assessments. Data collected from the port sampling programme was stored in the small pelagic database maintained by the division. The preparation of estimates with regard to 2020 is currently in progress.

The small mesh gillnet fishery data collected from 2000 – 2019 in the west coast fishery by this MBRD port sampling programme was analyzed with the aim of obtaining a better picture about the trends in the fishery. During this period, fishing operations were mostly conducted by OFRP boats using small meshed gillnets of mesh sizes ranging from 12 – 38 mm. The gillnets having mesh sizes of 22-38 mm were widely operated for catching herrings (Amblygaster spp.) and sardines (Sardinella spp.). An increasing trend in the average number of gillnet pieces in a fishing operation was observed in the west coast fishery (Figure 1).

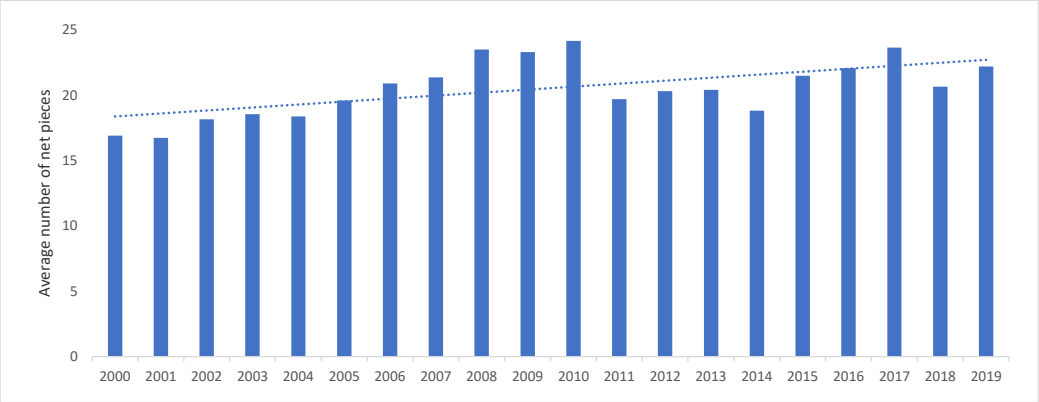


Figure 2.1-1. Gillnet usage in the small mesh gillnet fishery in the west, Sri Lanka operated targeting small pelagic.

Though the gillnet fishery was mostly operated targeting herrings, around 55% of the boats operated during this period had reported zero catch rates of herrings. Moreover, a strong seasonal fluctuation in the nominal CPUE of spotted sardinella (Amblygaster sirm) in terms of catch in kg/OFRP boat/hour was observed during this period (Figure 2-2). The highest annual average catch rate (56.38 ± 1.67) was reported in 2017 (Figure2- 3).

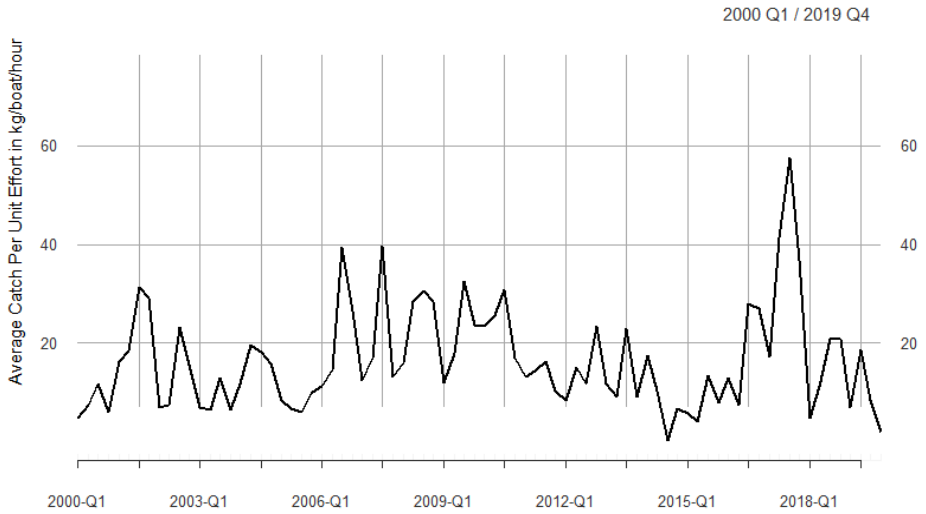


Figure 2.1-2 Quarter-wise variation in average Catch Per Unit Effort (CPUE) of spotted sardinella in the west coast small mesh gillnet fishery, Sri Lanka: 2000 -2019.

Unsustainable fishing practices exist in the small pelagic fishery such as effort increase, night fishing during spawning seasons and use of smaller mesh size gillnets targeting immature fish. At present, formulation of a Fishery Management Plan with regard to small pelagics in the west coast of Sri Lanka is in progress under the Norwegian technical guidance. Conducting a stock assessment for key small pelagic species in the west coast is also in progress with the technical support of the World Bank.

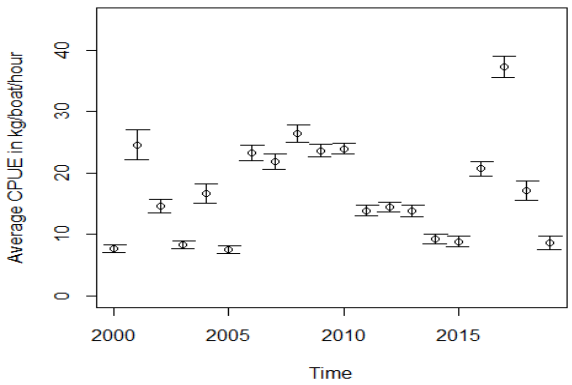


Figure 2-3: Annual variation in Catch Per Unit Effort (CPUE) of spotted sardinella in small mesh gillnet fishery in west coast, Sri Lanka: 2000- 2019

Spiny lobster fisheries management and in-situ conservation of berried spiny lobsters

Spiny lobster fishery in Hambanthota district has been identified as a major income source among the artisanal fishers contributing 60% to the total production of the country. Accelerated exploiting rate due to increasing foreign demand, catching berried females, environmental degradation, increasing fishing efforts and violation of the available regulations are the major causes for the decline of the stock size. A set of regulations has been implemented for the conservation and management of the stock. Hence this study was done to understand the current status of the fishery to adjust the management regulations.

Major lobster landing sites and collecting centers in the south (Weligama, Tangalle, Hambanthota, Kirinda and Amaduwa) were visited once a month for fisheries and biological sampling. Carapace

length, total length, sex, species composition presence or absence of external eggs or spermatogonia, craft type, gear and catch volume were recorded. In addition to the field sampling, berried lobsters were kept in the cage constructed at the Matara Polhena sea until they released their external eggs. This programme is continuing in collaboration with the Polhena fisheries co-management committee.

Among the five species of lobsters represented in the catch, scalloped spiny lobster (P. homarus) contributed 73%, *P. versiclor* 18%, *P. longipes* 1%, *P. penicillatus* 8% and P. ornatus less than 1% (only two lobsters within the year) to the catch. Mean carapace lengths of *P. homarus*, *P. versiclor*, *P. longipes*, *P. penicillatus*, and *P. ornatus* were respectively 7.47, 7.79, 7.72, 8.53 and 8.04 cm. Almost all the lobsters represented in the catch were above the minimum legal size and *P. homarus* mean CL was 1.47 cm above the minimum legal size. CPUE per three craft types non-motorized craft, motorized traditional craft and FRP boats were respectively 1.069 ± 0.789, 2.458 ± 0.527 and 1.622 ± 1.431. Length based spawning potential ratio was calculated only for the major species *P. homarus* because there was not enough data to calculate this for the other four species. F/M ratio for the healthy stock should be around 1 but the current value 2.3 (1.74 - 2.86, 95% confidence intervals) reflects the overexploitation level. Further, spawning potential ratio for *P. homarus* 0.26 (0.22 - 0.29) is very small and for healthy stock minimum SPR value should be at least 0.4.

The collected data is planned to be used for the World Bank funded stock assessment programme. Already a presentation has been done for the World Bank team regarding the output of the current project.

Biology and fisheries aspects of Blue sharks (*Prionace glauca)* in offshore waters of Sri Lanka.

Study on biology and fisheries aspects of Blue sharks (*Prionace glauca*) was carried out in the major shark landing fisheries harbours in Sri Lanka. The objectives of the study were to review the research findings on blue sharks in the Indian Ocean and to study the biological and fisheries aspects of blue shark's landings by the offshore fishing vessels. Fishery dependent data collection was carried out on a monthly basis in Negombo, Beruwala, Mirissa, Valachchenei and Trincomalee fisheries harbours. However, field data collection was not carried out from March-June 2020 and from October to December 2020 due to the COVID-19 pandemic situation. According to the findings a total of 1004 individuals of Blue sharks were recorded during the field surveys and average total length recorded was 298 ±18 cm for all landing sites. The size at maturity for the blue sharks was recorded as 201 cm. Catch Per Unit Effort (CPUE) for blue sharks was recorded as 8, 6, 5, 1 and 1 individuals/boat for Negombo, Beruwala, Mirissa, Valachchenei and Trincomalee fisheries harbours respectively. Sex ratio for the Blue sharks was recorded as 1:1 for all the blue shark landings. This study is an ongoing project which will be carried out in 2021 also. At the end of 2021 management recommendations will be made based on the data collected during the three years. In addition, a genetic study will be carried out to estimate the stock structure of the blue sharks.

Financial Allocation (Rs): 4,070,000.00

Financial progress (%): 98 Physical Progress (%): 95

2.2 Study of some biological and fisheries aspects of selected edible finfish species in the demersal fishery in the South-eastern coast of Sri Lanka

The present study was conducted to identify some important reproductive biological aspects of two edible reef fish species; *Epinephelus undulosus* and *Lutjanus fulviflemma*; and to understand the present status of the demersal fishery in South-eastern coast of Sri Lanka. The main objective of the study was to provide management recommendations for the proposed management plan for the demersal fishery in South-eastern coast of Sri Lanka, which will be formulated in collaboration with the Government of Norway under the Norway-Sri Lanka bilateral project. To fulfill the study objectives, a fishery-dependent survey was conducted. Monthly field visits had been planned to be conducted to the selected landing sites for the demersal fishery in Kalmunai and Tangalle fisheries district. The genetic study was conducted on the collected two edible reef fish species to identify the species and the nucleotide level variation and to study the phylogenetic relationship among species. However, due to the COVID-19 situation in the country, monthly field visits could not be conducted from March to June and from October to December in 2020. According to the findings of the study done during the rest of the year, 14 species were recorded in the demersal fishery catch in Kalmunai fisheries district among which *Lethrinus* spp. recorded the highest contribution by weight to the total catch at 51.11%. In the Tangalle fisheries district, 19 species were recorded in the demersal fish catch among which *Lutjanus quinquelineatus* recorded the highest contribution with 17.14% to the total catch. Considering the two dominant species in the catch; *Lethrinus olivaceus* and *Lethrinus lentjan* in the Kalmunai fisheries district, the recorded average sizes (TL) were 57.82 ± 16.82 cm and 35.17 ± 8.12 cm respectively. The size at maturity for these two species was 34 cm (TL) and 18 cm (TL) respectively. Accordingly, all the specimens of these two species in the commercial catch were mature ones and there was no apparent threat of capturing immature individuals of these two species in the Kalmunai fisheries district. However, due to the inconsistency of samples, a conclusion cannot be made on the reproductive biological aspects and genetic aspects of the selected fish species in the demersal fishery. It is suggested to conduct the study in 2021 to achieve the objectives of the study.

From the genetic analysis, morphology-only misidentifications of reef fishes at their species level were detected. DNA analysis identified samples collected as *Lutjanus quinquelineatus* as *Lutjanus rufolineatus*. Further, samples of *Lutjanus fulviflamma* analysed for genetic identification confirmed the species as *Lutjanus johnii*. These results emphasize that it is very important to carry out a comprehensive genetic study for a range of reef fish species in Sri Lankan coastal waters. Further, the current study highlighted the fact that there are inaccurate data recordings in the field due to the similar morphological appearances among reef fishes. Further, it is very important to update field guide, which will include a range of reef fishes with their prominent morphological features to reduce mis-identification of fishes. These will improve the precision of the data collections and final results. Further, these findings confirm the usefulness of DNA barcoding of reef fishes in Sri Lankan waters to improve the scientific knowledge as well as to improve the accuracy of the final result of reef fish data collections.

Financial Allocation (Rs): 1,330,000.00

Financial progress (%): 99 Physical Progress (%): 95

2.3 Sri Lanka – Norway Bilateral project to improve the management of fish resources of Sri Lanka (Phase II)

An increase in the number of fishing vessels and in the fishing effort in Sri Lanka, together with lack of data from the fisheries, have raised concerns that the stocks that Sri Lankan fishermen depend upon are over-exploited, and hence that the fisheries are not sustainable in the long run. The government strategy for enhancing the marine fisheries sector in Sri Lanka aims at developing the sector in a successful way using modern technology and scientific knowledge. Capacity building of Sri Lankan scientists is essential in this regard. Since knowledge about available fisheries resources and the level

of harvest are the compulsory inputs for fisheries management, independent resource surveys and landing statistics need to be given high priority.

In order to accomplish above objectives, the bilateral project between Sri Lanka and Norway commenced in late 2016. In the beginning of October 2018, an addendum to the contract with the Norwegian Embassy in Colombo was signed for extending the project period till 31.12.2019. Before completion of the project in 2019, a need arose to move forward the project as a new phase (phase II) from 2020 – 2022. Accordingly, all parties agreed for the second phase of the project.

WP 1: Fisheries dependent data

The Work Package 1 (WP1) of the project was initiated with the aim of improving the fisheries data collection system for marine fisheries in Sri Lanka to provide reliable statistical landing data covering the entire country for sustainable management of the marine fisheries. Three local partners are responsible for the implementation of this work package: MBRD of NARA, Department of Fisheries and Aquatic Resources (DFAR) and the Statistics Unit (SU) of the Ministry of Fisheries (MoF).

In work package 1, a baseline survey was conducted in 2017 and the survey data were evaluated and improved after that. The report from the baseline survey conducted by DFAR and NARA in 2017 was completed in 2018 and a sampling strategy was developed in 2019/2020 to ensure representative and reliable statistics for all marine fisheries, including coastal fisheries. An immense effort had gone into improving the quality of the baseline data, as errors occurred partly due to missing automatic validation when registering data. Enhancing data quality has been considered important, since development of sound sampling design depends heavily upon baseline data analysis and the quality of these data. Landing data was planned to be part of an integrated fisheries data system, which incorporates other data sources as well, for example vessel registry, licenses, and fishermen's registry. Integration of different related data sources into one system is considered a major strength, since it will enable coherent validation of data and more flexibility for analyzing and reporting outputs.

The formats of the data collection sheets developed in 2017 were agreed on by all parties. With the development of a new database, these data collection sheets were transferred into software applications for tablets, in order to register data electronically at the landing sites using tablets. The tablet application interface was developed in 2019/2020 based on developed paper sheets and database designs. A series of video meetings between the Norway team and Sri Lanka project partner agencies (NARA, DFAR and MFARD/SU) was held to discuss the WP 1 activities and the progress. A series of regular internal meetings was also held between NARA, DFAR and MFARD/SU to discuss about various subjects relating to WP1.

Twenty-eight and fourteen enumerators of DFAR and NARA respectively were trained in September, 2020 on the large pelagic port sampling data collection under the new system in fishery harbours using the tablet software. The objective of the training programme was to provide basic knowledge to them about new port sampling data collection. They were mainly trained on new tablet software applications and collection of data under the new system. Moreover, they were taken to the Negombo fishery harbour and were provided a practical training on the tasks that were assigned to them to be carried out at the field. The large pelagic data collection based on fishery harbours was started in October, 2020. Though the training programme with regard to coastal fisheries data collection was planned to be conducted in mid-October, 2020, it could not be conducted due to the second wave of COVID-19.

A separate data unit consisting of the officials of the MoF, DFAR and NARA has been proposed to be established at DFAR. In this regard, a draft TOR was prepared in 2020. A platform-independent

programme has also been developed to measure fish using a hand-held camera (e.g. smartphone). This will be made use in future in collecting length frequency data under the phase II of the project.

WP2: Fisheries Independent Surveys (Acoustic Surveys)

Acoustic surveys are used to estimate distribution and biomass (total weight of fish in a given area) of species living in open water (pelagic) and often aggregating in large schools. Even though it is a reasonably precise tool used in fish abundance estimates, it is largely underutilized for fisheries research in Sri Lanka. Notably, that was the very first survey for establishing a time series on pelagic resources on the North East Coast of Sri Lanka during the Southwest monsoon. The pelagic fish resource is one of the main sources of seafood in Sri Lanka, and these resources are being overfished at present. Therefore, the main objective of these acoustic surveys is to establish a time series on pelagic resources while producing indices on the status and development of the pelagic fish resources after the continuation of surveying for many years. This was the second acoustic survey with RV S*amuddrika* conducted on the NE coast in August 2020.

A survey plan was made prior to the survey. The plan originally indicated one stratum along the coast north of Trincomalee. A random, systematic zigzag transect design was chosen. The StoX application was used to define the strata boundary definitions based on available previous depth strata from the RV Dr. Fridtjof Nansen survey of 2018 to cover the depth range of 10 – 100 meters. This was assumed to cover the main range of distribution of coastal small pelagic fish. Acoustic data were collected using the EK 15 echosounder of the RV *Samudrika.* Plankton samples were collected in the middle of each transect along the survey track. (Figure 2-3)

Figure 2.3-1 Map of survey strata, Central East (CE) and North East (NE) with zigzag transects. Each stratum covers the depth range between 10 m and 100 m

The raw acoustics data from the EK15 echosounder was used for the post-processing in LSSS 2.6 application. Data were analyzed according to the predefined eight acoustic categories as listed in table 2-1.

Table 2.3-1 Acoustic groups used for the processing of raw data

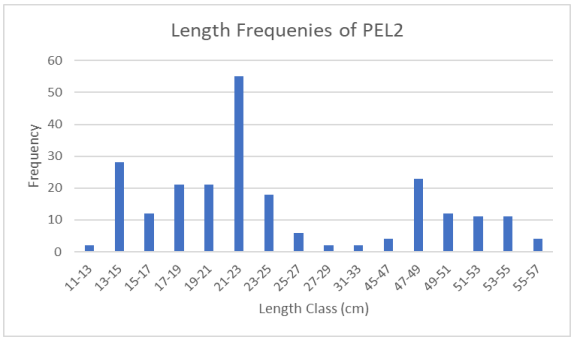
Name	Priority	Species / Groups
PEL 1	1	Herring- like (e.g., *Amblygaster sirm*)
PEL 2	1	Mackerel-like (e.g., *Selar crumenophthalmus*)
PELAG	1	Squids (e.g., *Loligo* spp.)
PLANK	2	Plankton
BOTTOM	2	Bottom Fish
HERR	3	Possible- Herrings
MACKE	3	Possible- Mackerels
OTHER	3	Other Species

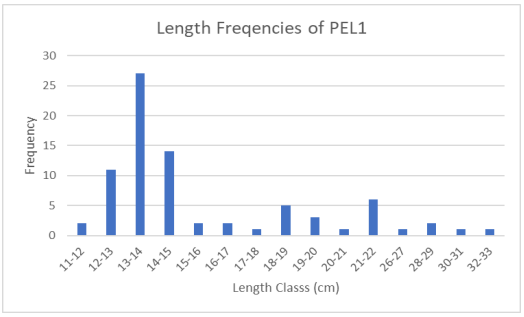
(1 – High, 2- Low, 3- useable)

Biological sampling of commercial catches was conducted parallel to the survey area, focusing on the landing sites, *Trincomalee*, *Salliya*, *Poduwakattu*, and *Pulmudai*. In this regard, two field research assistants were appointed to collect the fisheries and biological data, emphasizing catch composition. Here, they were instructed to pay more attention to the most abundant pelagic fish species, such as herrings (*Amblygaster sirm*) and sardines (*Sardinella* sp.), which are landed at the above landing sites. In addition, the catch data for the demersal fish and other species, which are contributing in considerable proportions to the total catch, were also collected. Further, length and weight data for individual fish were collected, which are leading to density and biomass estimation via acoustic methodologies.

Abundance estimates for acoustic categories PEL1 and PEL2 were calculated using StoX version 2.7 considering only one PEL1 and one PEL2 fish per stratum. These fish were given the average individual length and weight calculated from the biological samples from the nearby landing site.

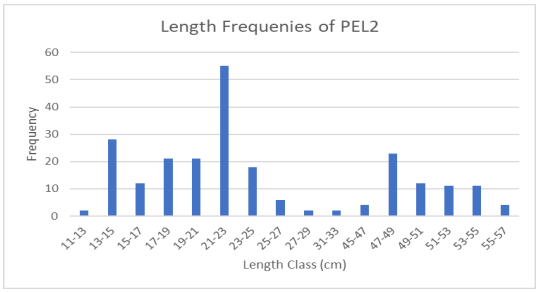
Length Frequencies for PEL1 and PEL2

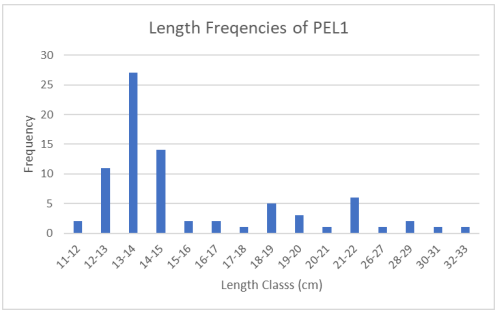




The estimated biomasses for PEL 1 and PEL 2 were 2,240.2 tons and 2,271.3 tons, respectively, for the survey area.

Fish Abundance





The estimated biomasses for PEL 1 and PEL 2 were 2,240.2 tons and 2,271.3 tons, respectively, for the survey area.

Financial Allocation (Rs): 1,190,000.00

Financial progress (%): 100 Physical Progress (%): 95

2.4 Studying the fisheries and marine mammal interactions and population estimate of blue whale (B. musculus)

Demersal and pelagic longline fisheries involve frequent and geographically widespread interactions with many individuals, populations, and species of marine mammals. Animals sometimes suffer mortality and serious injury following these interactions, attracted mainly to longlines as a source of food. This depredating behaviour can have serious consequences for fishermen, especially when they lose valuable catch and face other associated operational and regulatory challenges.

To study the fisheries and marine mammal interactions, a questionnaire survey was carried out based on the major fisheries harbours in Sri Lanka (Dikovita, Negombo, Beruwala, Dondra, Mirissa, Tangalle and Kirinda). The blue whale population size of Sri Lanka is estimated using the mark and recapture method through photos which are collected on a daily basis in collaboration with the commercial whale watching operators. Individuals (including re-sightings) were identified from South coast area. According to the results, Depredation Index (DPI) for the Tuna longline fishery is 14.4. Through the questionnaire survey of IMUL boats, four marine mammal species damaged to the hooked yellow-fin tuna, skipjack tuna, marlin and sailfish were identified. These species are

A. False killer whale - *Pseudorca crassidens*
B. Pigmy killer whale - *Feresa attenuate*
C. Melon-headed whale - *Peponocephala electra*
D. Short finned pilot whale - *Globicephala macrorynches*

The results revealed that black fish species (marine mammals) are very common along the equator but less around Sri Lanka. Therefore, depredation is frequently reported in deep sea areas within the EEZ and international seas along the equator. Through the Photo identification programme conducted in collaboration with commercial whale watching operators from January to mid-March 2020, 89 blue whale individuals were identified form Mirissa area including resighting. Based on the past and present studies two areas in south and east coasts around Mirissa and Trincomalee were proposed to declare as protected areas.

Financial Allocation (Rs): 672,000.00

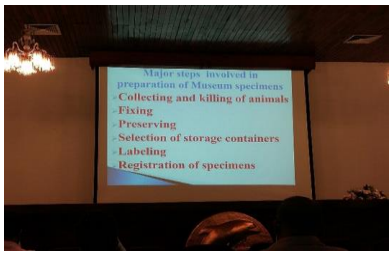
Financial progress (%): 100 Physical Progress (%): 95

2.5 Marine museum upgrade and skeleton preparation

Major objectives of this project were establishment of whale skeletons and specimens of ETP species to exhibit to the public and to upgrade the marine museum opened to the public. During the February an attempt was made to recover a skeleton of a buried stranded whale which had been identified as belonging to a Bryde's whale (*Balanoptera* spp) buried in 2018 at Uswetakeyyawa, near Pegasus Reef Hotel. But after the preliminary investigations it was found that some part of the skeletons had washed into the sea due to the rough sea conditions during the monsoon period. A one-day training workshop was held to train Scientists and Research Assistants of MBRD regarding preservation techniques of the marine museum specimens by the curator of the museum of Department of Zoology of University of Sri Jayawardhanapura. Up until now, fish samples have been preserved in formalin for museum preservation purpose. But due to its carcinogenic effect, it was we decided to use ethanol as the preservation media instead of formalin. Preservation of rare samples collected during the Dr. Fridtjof Nansen survey was started with this knowledge. Required glass tanks were prepared for the preservation and formalin preservation was used to preserve the samples until the ethanol for the preservation is purchased. Ethanol purchasing process was also started. But these activities were interrupted due to the COVID-19 pandemic situation.

Financial Allocation (Rs): 672,000.00

Financial progress (%): 97 Physical Progress (%): 60



Workshop on specimen preservation techniques

3 Inland Aquatic Resources and Aquaculture Division

3.1 Effects of sediment enrichment with sea grass and macro-algae, on the behaviour, growth, and survival of juvenile sandfish, *Holothuria scabra* grow out farming in a sea pen in Northern Province in Sri Lanka

Officer/s responsible: P. A. D. Ajith Kumara and C.B. Medagedara

Introduction:

Although there were advancements in hatchery production of sand fish **,** *Holothuria scabra* there are still bottlenecks in methods to ensure high survival and growth of cultured juveniles to reach market size (>320g) through grow-out culture in pens and sea ranch sites in Sri Lanka. However, studies aimed at increasing survivorship of sea cucumbers at sea are limited. Previous studies have shown that sediment characteristics, such as organic matter content, microalgae, bacteria, and grain size may be significant factors that determine sandfish growth and survival. Continuous culture trials in same location without supplementary feeds eventually cause to growth retardation due to unavailability of

natural foods. Therefore, appropriate sediment enrichment method needs to be introduced to enhance the growth.

Specific Objective/s:

i). to investigated the effect of sediment enrichment with aquatic macrophytes (i.e. seaweeds and sea grass) on the growth, survival, and diel burying behaviour of juvenile sandfish rearing in sea pen

ii). to examined the temporal and spatial relationship between sediment food abundance and juvenile feeding activity in terms of growth performance

Activities proposed to be completed during the period:

1. Broodstock collection and conditioning
2. Facilities construction & rehabilitations
3. Commercial pen monitoring
4. Investigation of micro habitat conditions
5. Analysis of soil sediment samples
6. Conduct awareness programmes

Results: Activities carried out:

Broodstock conditioning and facilities rehabilitation works carried out at NARA Regional Center Kalpitiya and Serakkuliya area. Monitoring of commercial farming, theirs micro habitat conditions and GPS locations were obtained in Kaytz and Vellanei DS divisions Jaffna district. Among these a suitable farm was selected for experiment rearing of sea cucumber juveniles in Aleipiddi area in latter DS division. Juveniles were arranged from a private hatchery at Ariyalei area. Net materials were weaved attaching small fine mesh to prevent juvenile escape. Initial organic matter contents of the bottom soil were calculated having obtained five samples from the farm. Organic matter (%) in dry weight of five samples were ranged from 0.08- 1.78. Sediment quality of five sampling locations was estimated by standard sieve fractionation method and results are shown in table 1. Habitat improvement work carried out before start culture trial. For this, detached sea grasses were put in to poly-sack bags and weighed (25 kg) then deployed inside the pen with the idea of assessing decayed rate.

Table 3.1-1 Sediment quality of five sampling locations

Sediment Composition		Percentage Value in Range
Sand (g/100) (%)	< 2 mm	91.19- 98.85
Gravel (%)	> 2 mm	1.78-8.25
Silt and clay	< 63 *m*m	0.98-1.85

Conclusions

The selected site to be performred sea cucumber juvenile culture trial is poor with oraganic matters when compare with other sea cucucmber farms in the area. This matter also clearly revealed from that the result obtained from sediment analysis data which shows higherst percentage of coasre particles (table 1). Therefore, commercial culture trials in the site has been continulosly faliured and exhibited poor growth rate and growth retardation of cultured organisms due to lack of foods.

Recommendations- None

Outputs & outcomes

Several GIS maps were prepared to indicate sea cucumber farming and abondoned sites in Jaffna. Exploratory effect of micro-habitat conditions were evaluated being detailed analysed of sediment samples (5 no‘s). Accordingly, one culture site was selected/identified.

Constraints:

As lock down of country after 17th March 2020 all the field works had to stop. Only one field visit had been completed during the first quarter of the year. When the country re-opened in June there wasn’t enough time to complete the one-year culture cycle including 60 days nursery period, therefore this project was give up with the idea of continuation in the following year.

Financial Allocation (Rs): 360,000.00

Financial progress (%): 15 Physical Progress (%): 12

3.2 Assessment of fisheries & aquaculture potential in floodplain ecosystem of Nilwala river basin in Sri Lanka.

Responsible Officer : K.W.R.R.Amaraweera

Introduction:

Flood plains are the relatively flat lands adjacent to a body of water, such as a river or stream, that become flooded (inundated with water) when channel capacity is exceeded and overtopping occurs. Nilwala is one of the longest rivers (78 km) in southern Sri Lanka flowing through Matara District. During the rainy season low lands of river basin are inundated by floods and render the land unavailable for crop production. According to the Department of irrigation Inundation area map Nilwala river basin in May 2017, 12.6% of the total land area of Matara District was inundated by floods. Flood water and lands are considerably underutilized and can be used for aquatic productivity (Dey M. M. *et. al* (2006)). According to a study conducted by IUCN Sri Lanka (2005), 25 species of fish inhabit Kirala Kale wetland in Nilwala river basin. Therefore, it is worth to carry out a survey on aquatic biodiversity and assess the fisheries and aquaculture potential in those flood affecting areas to uplift the economic and social status of the local community.

Thihagoda, Malimbada, Athuraliya, Matara and kamburupitiya are the most inundated DS divisions of Nilwala river basin for example at least 30% of total lands in each DS division was inundated by floods in May 2017 (Inundation area map, Nilwala gaga basin in May 2017, Department of irrigation). These divisions consist of considerable resources such as abandoned paddy fields, swamps, Marshes, and minor reservoirs which can be used for aquaculture and fisheries productivity. There is no special project or plan to develop aquaculture and fisheries in Nilwala river basin at the moment but small scale (daily consumption levels) fisheries activities are taken place. Proposed study will result a comprehensive analysis of the full aquaculture and fisheries potential in the area.

Objectives:

- To assess aquaculture potential in Nilwala river basin
- To get the maximum utilization from flood plain for aquaculture production
- To assess land use patterns, ecosystem services, fish biodiversity in Nilwala river basin
- To engage the community people towards a sustainable production system from which they can improve their socio-economic condition.

Methodology

A preliminary survey will be carried out to demarcate flood plain areas of Nilwala river basin.
Suitable sampling locations will be selected for collecting environment data
According to the flood, water availability and rainfall data (Department of Irrigation)
Data collection in suitable sampling location
Water quality parameters - T, pH, DO, salinity, Turbidity, Nitrate, Phosphate, chlorophylla
Heavy metals - Cd, Pb, As, Hg

soil quality - soil type, pH
Conducting socio-economic & land used patterns survey vulnerable families in 20 DS divisions in Matara District.
Monitoring riverine fishery in floodplain
Preparing seating maps on aquaculture potential areas using GIS
Carry out awareness workshop for transferring knowledge between relevant groups

Results

Table 3.2-1 Ranges for recorded water quality parameters selected sampling sites during the study

Site	T water	D.O	pH	Turbidity	Alkalinity	Hardness	Total Ammonia	Unionized NH_3	Phosphate	Nitrate
Diyagaha West	29.5-31.00	0.63-1.7	7.19 – 7.97	5.6 – 33.12	22.5 – 37.5	46 – 70	1.4 – 1.5	0.012-0.0379	0.18 – 0.3	0.8 – 1.8
Samaradeniya wewa	30 – 31.5	3.99-4.7	7.18 – 7.82	41.13-17.27	25 – 35	14 – 22	0.4 – 0.7	0.003-0.0296	0.22 – 0.35	0.8 – 1.4
Navimana South	30.5-31.5	4.12-4.37	7.05 – 7.72	19.55-20.43	27.5 – 40	21 – 28	0.5 – 0.5	0.002-0.0211	0.2 – 0.27	0.9 – 1.7
Kirala kale)	30.5 – 32	1.66-1.52	7.02 – 7.37	12.01-21.28	25 – 37.5	40 – 44	0.2 – 0.9	0.1 – 0.0155	0.04 – 0.16	1 – 1.3
Godagama	30.5 - 31.52	1.97 - 2.89	6.89 – 7.28	17.09-45.64	45 – 55	51 – 58	0.4 – 1	0.002- 0.011	0.1 – 0.34	0.9 – 1.4
Nadugala 1	31.5 - 32.5	1.97 - 1.97	4.88 – 5.01	16 – 17.12	12.5 – 15	289 – 350	3.6 – 9.7	0.0216- 0.05	0.16 – 0.16	0.16-1.3
Galboda Udugama West)	31.5-32.5	2.14-6.9	6.71 – 6.77	38.76 – 84	55 – 80	48 – 66	2.3 – 4.7	0.011-0.0324	0.03 – 0.39	0.03-1.3
Watagedara west	32 – 32.5	0.66-0.9	6.7 – 6.75	52 – 82	55 – 60	46 – 56	0.2 – 2.8	0.001-0.0193	0.13 – 0.16	0.16- 0.4
Palakathalagoda	30.5 – 32	0.64-2.82	6.48 – 6.65	9.7 – 17.22	25 – 35	14 – 64	1.2 – 1.9	0.0082-0.009	0.08 – 0.18	0.18-0.8
Watagedara East	31.5-32.5	0.93-1.87	6.8 – 6.74	14.89-17.37	37.5 – 45	30 – 30	1.2 – 1.5	0.006-0.0103	0.3 – 0.12	0.12-0.8
Katuwangoda wewa	31.5-32.5	0.7-0.63	6.88 – 7.03	23.09-71.74	30 – 57.5	22 – 47	0.1 – 0.8	0.0005-0.0088	0.1 – 0.21	0.8 – 0.9
Kos Induwa Yaya	31.5-32.5	0.54-0.91	5.01 – 6.55	91 – 51	52.5 – 67.5	46 – 58	0.5 – 0.9	0.0062-0.026	0.15 – 0.17	0.8 – 0.9
Sulthanagoda Wewa	30.5-32.5	7.34-8.46	6.77 – 6.88	27.64-28.41	22.5 – 40	13 – 22	1.8 – 3.9	0.009-0.0429	0.05 – 0.05	0.4 – 0.5
Sulthanagoda South	30.5-31.5	1.6-1.97	6.75 – 6.91	22.76-33.06	80 – 85	72 – 74	0.1 – 0.5	0.0005-0.0034	0.08 – 0.15	0.1 – 0.2
Kithanawala Wewa	30 – 32.5	0.76-5.17	7.18 – 7.19	18.51-18.64	17.5 – 20	14 – 41	0.6 – 1.3	0.004-0.0143	0.15 – 0.17	0.3 – 0.6
Kosgaha benaya	31 – 32.5	4.23 - 5.04	7.02 - 7.68	14.52 - 17.64	40 – 45	23 - 30	0.1 - 0.7	0.0005-0.0189	0.15 – 0.17	0.4 – 0.8
Pahala Athuraliya	30.5-31.5	3.67 - 4.97	6.89 – 7.09	18.42-24.73	17.5 – 20	16 – 10	0.1 – 0.8	0.0005-0.0055	0.14 – 0.18	0.3 – 0.7
Kanahalagama Wewa	29.5-31.5	3.2-4.77	6.4 – 7.03	6.15-22.16	22.5 – 42.5	14 – 40	0.2 – 0.4	0.0013-0.002	0.16 – 0.85	0.3 – 0.9
Nagoda Watiya	30.5 – 32	1.5-3.16	6.68 – 7	25.29-27.4	40 – 50	38 – 38	0.1 – 0.1	0.0005-0.0048	0.1 – 0.13	0.6 – 0.6
Karathota Uyangada 2 West	31.5-32.5	1.27-1.9	6.86 – 6.89	16.54-37.59	52.5 – 105	66 – 74	0.1 – 1.1	0.0005-0.0075	0.23 – 2.41	0.4 – 0.6

Table 3.2-2 Soil texture- selected sampling sites during the study

Place	Soil pH	Sand %	Clay %	Silt %	Soil Type	Remark
Diyagaha-West	6.86	20	25	55	Silt loam	
Samaradeniya Wewa	6.61	18	23	59	Silt loam	
Navimana-South	6.76	5	17	78	Silt loam	
Kiralakale	6.5	4	34	62	Silty clay loam	suitable for fish pond construction
Godagama	6.72	12	15	73	Silt loam	
Katuwannagoda Wewa	6.59	9.5	36	54.5	Silty clay loam	suitable for fish pond construction
Kos induwa yaya	6.47	6.6	38	55.3	Silty clay loam	suitable for fish pond construction
Sulthanagoda Wewa	6.74	23	12	65	Silt loam	
sulthanagoda south	6.51	10	24	66	Silt loam	
Nadugala 1	6.74	13	21	66	Silt loam	
Galboda Uduwa west	6.8	4	54	42	Clay	
Watagedara West	6.6	5	30	65	Silty clay loam	suitable for fish pond construction
Palakathalagoda	6.42	9.5	45.5	45	Silty clay	
Watagedara East	6.23	9.09	54.5	36.3	Silty clay loam	suitable for fish pond construction
Kithanawala Wewa	6.9	10	56	34	Clay	
Kosgahabenaya wewa	6.25	7	24	69	Silty clay loam	suitable for fish pond construction
Pahala athuraliya	6.12	8	28	66	Silty clay	
Kanahalagama Wewa	6.54	62	22	18	Sandy clay loam	suitable for fish pond construction
Nagodawatiya Wewa	6.35	5	42	53	Silty clay	

Riverine fishery in Nilwala flood affected areas

Table 3.2-3 Riverine fisheries societies in Nilwala flood affected areas

Fisheries society	Description
Kirala kale	Daily consumption level fishery
Kadawaduwa/Bandaththara	small scale artisanal fishery
Sulthanagoda	Daily consumption level fishery
Katuwangoda	Daily consumption level fishery
Kosgahabenaya	Daily consumption level fishery
Nagoda watiya	small scale artisanal fishery
Thudawa	small scale artisanal fishery

Table 3.2-4 Riverine fishery at Bandaththara Nilwala River

Craft type	Non mechanized fiber, sometimes tubes
Fishing operation	Day or Night, Day time - fish, Night time - Prawns/fish , one / two / three fishers
Fishing duration	Six/seven/eight hours per day
Number of fishing trips	one trips per day, 20 - 24 trips per month

Fishing Gears	Gill nets- fish (Nylon mesh size 3.5/4/4.5 inches ,Two/Three pcs)
	Cast net-Prawn/fish, Hook and line – fish no7/9
Yield	5 – 7 kg per trip for one fisher
Income	Rs (1200 to 2500)per day

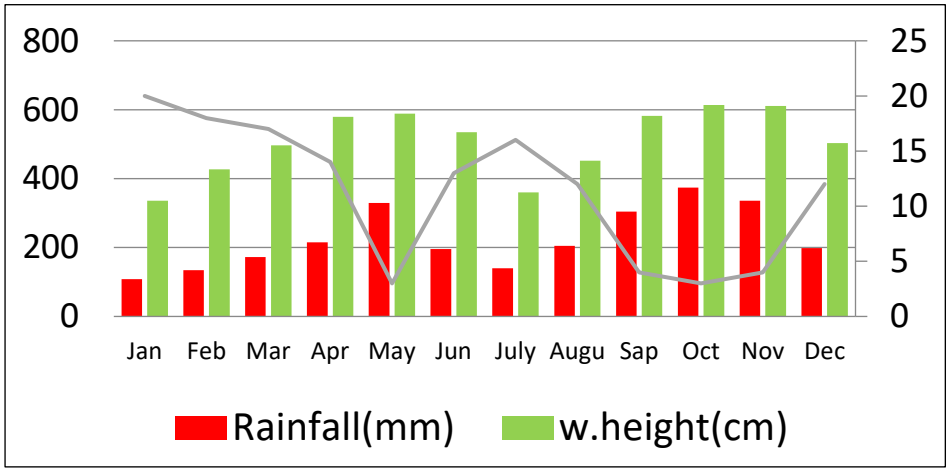


Figure 3.2-1 Fluctuations of mean rainfall,Water height & Catch per boat (2001-2019)

The highest rainfall was recorded in May and October months and the lowest rainfall is recorded January to March.

The bimodal rainfall pattern can be seen due to monsoons and cyclonic depressions. One high value is highlighted in May representing South East Monsoon (SEM) and the other high value occurs in October representing cyclonic depressions.

Fish catch per boat fluctuate according to the fluctuation of rainfall & water height.

Out of the three hydrological parameters, rainfall, water height and river discharge, rainfall showed the strongest negative correlation with fish catch per boat (r= -0.976, p= 0.000).

When water depth increases, distribution of fish per unit volume decreases, unless they are migratory species which swim upstream for spawning in shoals.

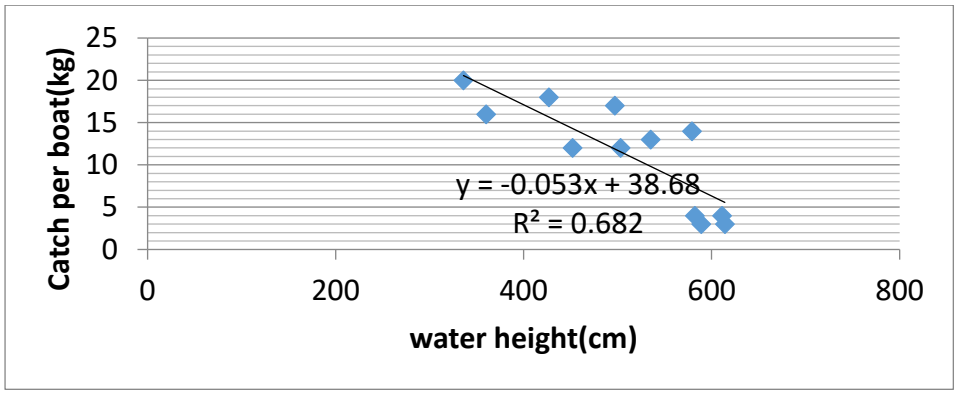


Figure 3.2-2 Relationship between fish catch per boat & water height

Strong correlation between percentage of active fishers engaging in fishing and the fish catch per boat(r= 0.910, p=0.000)

Suggested that the fish Catch per boat has increased during dry seasons because the water depth is low and the probability of fish getting tangled in nets or captured by other fishing gear is high when the water level is low.

Most flood events can be occurred during May, October, November and December in lower lands of Nilwala river

The corresponding water level of floods alert, minor floods and major floods are 5m,6m and 6.5m respectively.

Rainfall and floods an impact on fishing activities such as reduction in number of fishers engaging fishing, and fish catch per boat.

Fish bio-diversity survey at Kiralakele area

Table 3.2-5 **Recorded fish species and abundances of fish**

Fish species	**common name**	**No of fish**
Oreocromis niloticus	Nile tilapia	3
Etroplus suratensis	Green cromide,Perl spot	10
Osphronemus gourami	Giant gourami	2
Anabas testudineus	Kavaiya	2
Chana striata	Striped snakehead,Loolla	1
Labeo rohita	Rohu	1
Labeo dussumieri	common Labeo,Hirikanaya	1
Catla catla	Catla	1
Macrobrachium rosenbergii	Giant freshwater prawn	24
Orecromis mossambicus	Mozambique tilapia	11
Heteropneustes fossilis	Asian stringing cat fish, Hunga	60
Puntius sarena sarena	Mas Pethiya	3
Chana punctata	Kanaya	3
Mugil cephalus	Godaya	2
Carangoides fulvoguttatus	Thumba Paratiya	1
Magalop cyprineides	Elaya	1
Peneus indicus	Kiri Issa	2

Preparation of seating maps on aquaculture potential areas using GIS

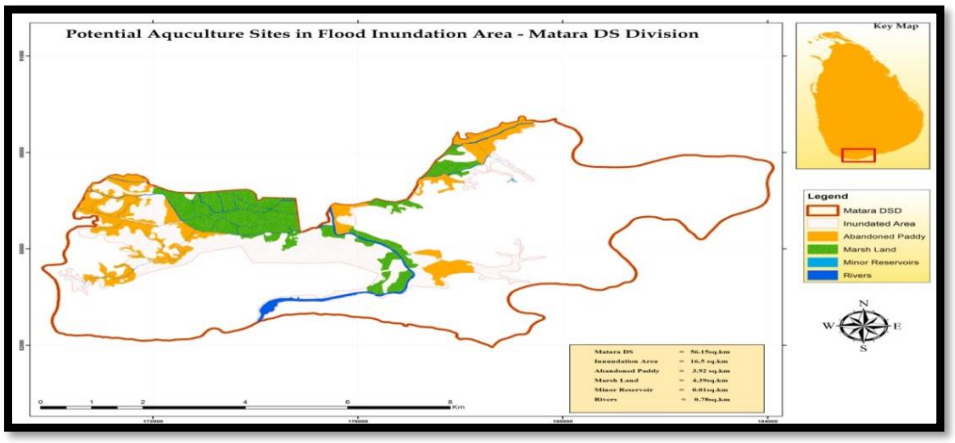


Figure 3.2-3 Aquaculture potential areas in Matara DS Division

GIS Map 02 - Aquaculture potential areas in Thihagoda DS Division

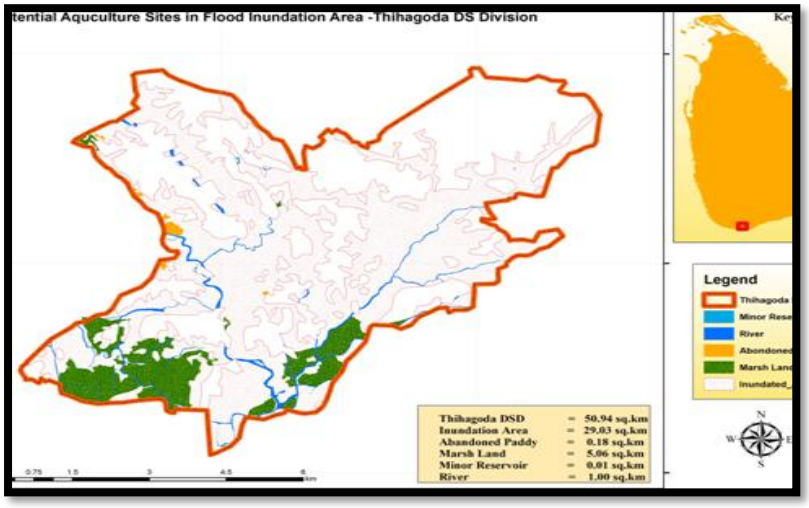


Figure 3.2-4 Aquaculture potential areas in Malimbada DS Division

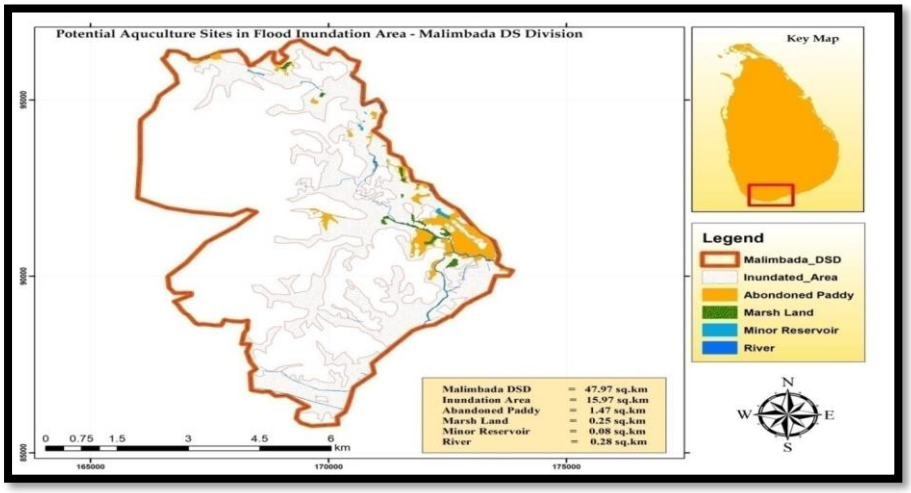


Figure 3.2-5 Aquaculture potential areas in Athuraliya DS Division

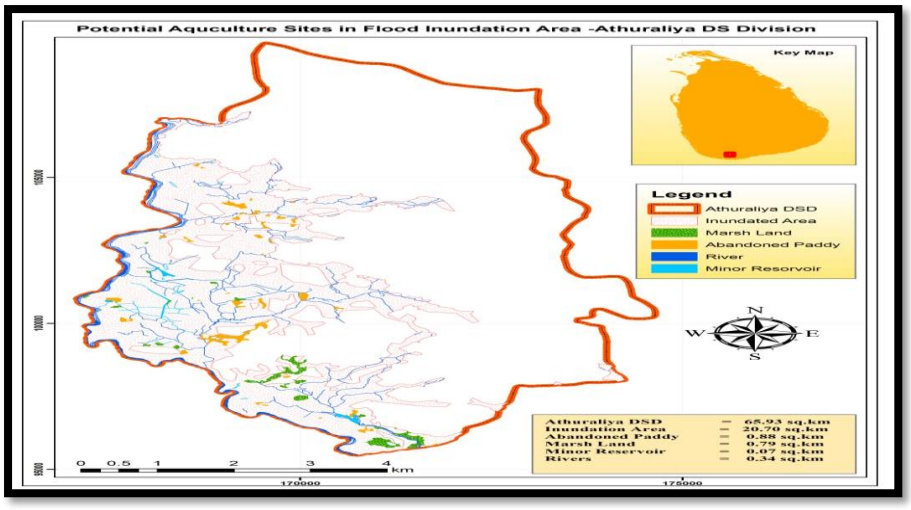


Figure 3.2-6 Aquaculture potential areas in Kamburupitiya DS Division

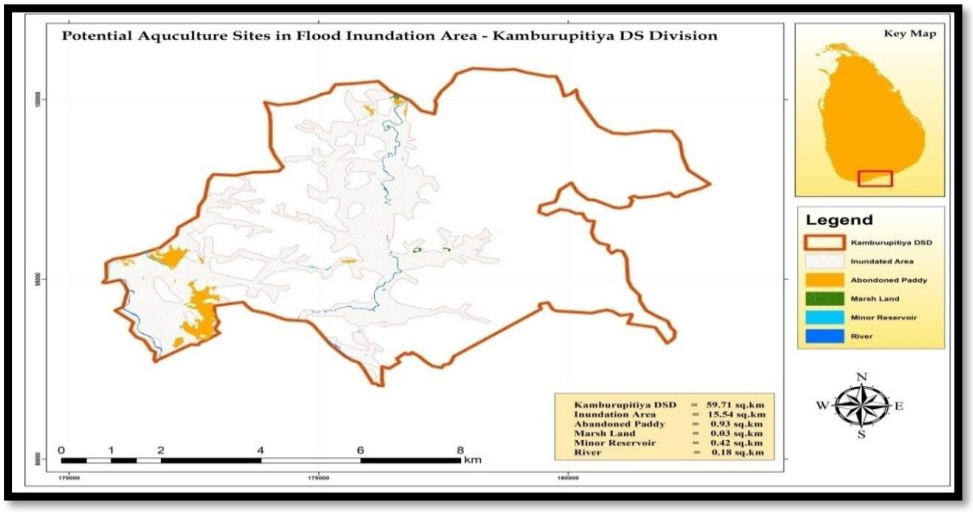


Figure 3.2-7 potential Aquaculture areas in D.S. divisions

Table 3.2-6 Crop calendar for flood plain Nilwala River for Gift Tilapia

DS Division	**Potential Aquaculture Area km^2**
Matara	9.1
Thihagoda	6.25
Malimbada	2.08
Athuraliya	2.08
Kamburupitiya	1.56

Table 3.2-7

Seasons	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Rainy				+	+++	+			+	+++	+	

Flood					++					++	+	+
Dry	++	+ +	+				+					
Activities												
Pond preparation	+	+					+	+				
Pond drying	+	+					+	+				
Water pumping			+	+					+	+		
Fertilizing pond			+	+	+				+	+	+	
Stocking			+	+					+	+		
Rearing			+	+	+	+			+	+	+	+
Harvesting	+	+					+	+				

Recommendations & conclusions

Thihagoda, Malimbada, Athuraliya, Matara and Kamburupitiya are the most flood inundated DS divisions of Nilwala river basin for example 30% of total lands in each DS division was inundated by floods.

Water quality parameters and soil qualities in **s**elected sites (20 Sites) in Nilwala floodplainsuitable forfish culture development.

According to the prepared GIS map the highest potential aquaculture area is recorded in Matara DS Division. The calculated potential aquaculture area in Matara DS Division is 9 km ^{2} & it is 50% of total flood inundation area in Matara Ds division.

According to the socio-economic survey vulnerable families in 20 GS divisions more than 60% paddy lands were abounded due to the floods and failures of Nilwala scheme. It was recorded that vulnerable families have knowledge or experience in fish keeping (< 5%). Most farmers in Matara DS Division use abandoned paddy field for alternative cultivation of green leaves.

In riverine fishery, Tilapia, Giant gouramy, Loolla, are the preferred fish species &the most Valuable species is freshwater prawn.

Heavy rainfall and floods effect on fishing activities such as reduction in number of fishers engaging fishing, and fish catch per boat.Fish farmers of flood prone area should have to improve adaptable measures to cope challenges at the farm level.Small scale fish farmers can adapt to small changes but they can't adapt for rapid changes in flood prone areas.Fish farmer needs to be assisted by scientific research and technology to find solutions that will allow them to adapt to future challenges.

It is recommended that the government and other stakeholders should help enhance resilience of fishing communities by supporting existing adaptive livelihood.

Strategies and management institutions support adaptation to high rainfall and floods.

Out put

GIS maps for Thihagoda, Malimbada, Athuraliya, Matara and Kamburupitiya DS divisions on aquaculture potential areas

Crop calendar for flood plain Nilwala River for Gift Tilapia.

Outcomes

Development of fish culture in flood plain of Nilwala river

Alternative live hood for rural commiunities

Conclusion

The values of water & soil quality parameters in Selected 20 sampling sites within the recommended ranges for fish culture development. Since abandoned flood lands can be used for Aqua culture development.

According to the prepared GIS map calculated potential aquaculture area is 9 km ^{2} in Matara DS Division & it is 50% of total flood inundation area of Matara Ds division.

Constraints:

Field visits and project works were stopped or delayed for 4 months due to the Covid-19 situations in year 2021.

Financial Allocation (Rs): 720,000.00

Financial progress (%): 100 Physical Progress (%): 85

3.3 Experimental reef restoration for enhancing the spat availability and Improving spat collection methods for commercial scale oyster farming

Officer/s responsible : A.S.l..E. Corea, C. B Medagedara & V. Pahalawattaarachchi

Introduction

Edible oyster culture is expanded as a community based projects among fisher communities in the Puttalam district. Collecting sufficient spat for commercial culture has been a draw back for further expansion. Although spat collectors have been introduced for collecting spat, collection can be done only at Gangewadiya as there are no other oyster beds with sufficient breeding oysters close to culture locations. Therefore this project was designed to build new oyster beds (Oyster reefs) so that breeding populations will be increased and spat availability will be increased. The new reefs were to be shifted to locations close to culture areas so that collection of spat will be easy when it is near the farming sites.

Goals and objectives

Increase the commercial bivalve culture among fisher communities
To build more oyster reefs so that a steady breeding population is established in areas suitable for culture
Monitor breeding activities and any impacts to the new reefs so that the reefs could develop in the area as permanent oyster beds.
To Improve oyster spat collection and culture techniques
Disseminate technical knowhow among oyster farmers

Methodology

Artificial reefs prepared and allowed to grow on the Gangewadiya site until they contained sufficient population of adult oysters.
These were shifted to locations in Kalpitiya so that new oyster reefs are in function and could have a new breeding population. It will support spat collection in areas close to culture sites.
Reefs shifted to suitable sites were monitored and their growth and survival was monitored together with water quality and spat production
For monitoring conditions near artificial reefs spat collectors were deployed
Awareness programs for the community conducted for dissemination of knowledge

(1st year –2018 - reef building and monitoring of spat growth on reef structures with water quality
2nd year – 2019 - reef shifting &monitoring to see the growth of the new oyster population in new location
3rd year – 2020 - monitoring the growth and breeding of new population and the spat availability.)

Results

Reef monitoring

The 2 reefs that were shifted were monitored for their growth and spat production with water quality and a new reef was planned to be shifted to another location (then altogether 3 reefs) the new reef was shifted to Site 1 after COVID 1st lockdown where the previously shifted reef was damaged.

The monitoring was done in February and spat collectors were deployed near the 2 shifted reefs for monitoring spat fall. The reef area was $6m^2$ and the mean number of live oyster brood stock in new reefs were 412.25 ÷23.8 /0.25 m^2

But reefs could not be monitored due to COVID 19 Lockdown since mid-March where NARA RRc was made a COVID quarantine center. The sites were visited in July and one reef was damaged by fouling organisms. It was also broken and many adult oysters were dead.

Figure 3.3-1 Cleaning damage reefs and collectors after COVID

The other reef was completely damaged and the poles holding the reef were not found but 2 reef structures were recovered from the area. Since these had fallen to the ground and had not been cleaned silt had accumulated. All but 12 oyster in the 2 box structures recovered from this site were dead.

Reef structures built and stored at NARA had been thrown away when the building was used for COVID activities

Figure 3.3-2Thrown Reef structures and :Reef newly

built in august after COVID

One new reef was rebuilt in august in Kalpitiya but was monitored only once in September before the second COVID 19 lockdown.

Therefore, the monitoring the performance of the new reefs for breeding and spat production could not be carried out properly during 2020 as on 3 field visits have been carried out properly due to COVID 19 Lockdowns.

Spat collection

From the spat collectors deployed in the Gangewadiya area it was noted that the new plastic shellstructures that were introduced at the end of 2019 had 1-2 oyster attached to each shell. Total number of spat collected during the year was over 10000.

Figure 3.3-3 Spat attached to plastic shell like collectors

Figure 3.3-4 Spat attached to pvc collectors

From the PVC collectors deployed yielded 5102 spat in March and 5348 spat in August/September

Water quality in the original site and the new reef site was monitored when field work was possible.

Table 3.3-1 Water quality in the original site and the new reef sites

	Site with collectors	Natural oyster reef site	New reef site 1	New reef site 2
Salinity (ppt)	28 ± 2.4	30 ± 3.1	27 ± 3.4	32 ± 2.1
pH	7.8 ± 0.2	7.9 ± 0.2	7.7 ± 0.25	7.9 ± 0.3
Water depth (cm)	65 ± 12	50 ± 7.2	55 ± 6.3	45 ± 3.8
Ammonia (mg/l)	0.09 ± 0.001	0.02 ± 0.0009	0.03 ± 0.001	0.01 ± 0.0008

Nitrate (mg/l)	1.9 ± 0.1	1.7 ± 0.13	1.5 ± 0.11	1.8 ± 0.08
Nitrite (mg/l)	0.005	0.002	0.003	0.003
Phosphate (mg/l)	0.1 ± 0.003	0.08 ±0.001	0,02 ±0.0007	0.001

Maintanance of depuration plant and improving hygienic conditions

(Number of oysters depurated during 2020)

Knowledge dissemination - Awareness programs

(Any awareness programmes conducted)

Financial progress (%): 99 Physical Progress (%): 95

Constraints:

Cancellation of field work during most parts of the year due to COVID disease situation affected the progress of the project.

Inability to monitor reefs and collectors during COVID was a major drawback as reef performance and spat production from new reefs could not be monitored. Therefore success of using reefs for spat production cannot be commented.

Breaking and destruction of reefs durig COVID period caused a problem as new reefs had to be rebuilt and even that could not be monitored during the second COVID period

Since the chemicals requested for project work was not received analysing water quality for some parameters was not done

Recommendations:

Should monitor reefs for their performance and any problems

Financial Allocation (Rs): 735,000.00

Financial progress (%): 99 Physical Progress (%): 45

3.4 Survey on natural pearl oyster resource in North West & East coasts regard to regain the pearl industry in Sri Lanka

Officer/s responsible : C.B Medagedara, Pradeep Chathuranga

Specific Objectives

- Survey on natural pearl oyster stocks in Silwathura
- Identification of culture site in East coast and continue culture trail in North West coast
- Identification on suitable culture methods for pearl oyster culture

Introduction

The Black-lip pearl oyster *(Pinctadamargaritifera)* has long been an important species in the Indo-Pacific region mainly because of its beautiful shell, which is lined with a shiny and iridescent coating called na**cre** (Simon & Maria, 1999). The natural pearl of this species is highly valuable as a gemstone in jewellery industry. In addition, it is also believed to increase fertility and is hence recommended for women suffering from hormonal, fertility and menstrual problems. It is also believed to prevent heart diseases, eye diseases, digestive ailments, and to alleviate allergies and their effects.

Activities carried out and results:

a.Activities carried out to take pearl oyster from natural bed and restocked at Kiranchi

Mature Pearl oyster sampleof 800 no's bivalves drawn from Silawathura(E 79.43.49.29 / N 8.44.49.29)sea area. Samples were stocked in plastic box until transported safely to coast, samples were covered using wet gunny bags to increase moisture content and maintained liveness. Then samples were transported to Kiranchi area by vehicle and it took only two hours. Oyster rafts already prepared by wooden reaps and floating materials also attached increasing floating ability. Pearl oyster samples were stocked in special culture bags and plastic structures with the amount of 35-40 individuals per bag. Prepared oyster rafts were launched in selected deep trenched sea cucumber farm and oyster bags tied up. Sample sizes were recorded, shell height shell length and shell thickness parameters respectively. Level of salinity was recorded as 33ppt. Oyster rafts were anchored using 25 Kg cement blocks and 10mm nylon ropes. Oyster culture bags were suspended in water. Oyster associated sea grasses also sampled. Sample sizes were recorded shell height, shell length and shell widthparameters (39.55 ± 4.30mm, 46.97±4.69mm, 18.15± 2.00mm)

Figure 3.4-1 Mature pearl oyster samples

Figure 3.4-2 Associated sea grass samples

Figure 3.4-3 Restocking of pearl oyster samples on floating raft at Kiranchi And Survey on natural pearl oyster stocks in Silwathura

Underwater survey to find extent and stocking density of pearl oysters planned to conduct during month of March 2020. South West monsoon period started at the mid of March and fishermen in Silawathura refrain from sailing to sea. Corona outbreak was severely affected on planned underwater survey still at the end of October South West monsoon is going on. There were identified two beds of pearl reserves located 5Km apart each other. Oyster samples for restocking purpose obtained from bed number 01 and important observation was only mature oysters and spat falling or spats attached to mature oysters were not observed. Associated sea grass species were identified as *Halophila sp*. and *Padina sp.*

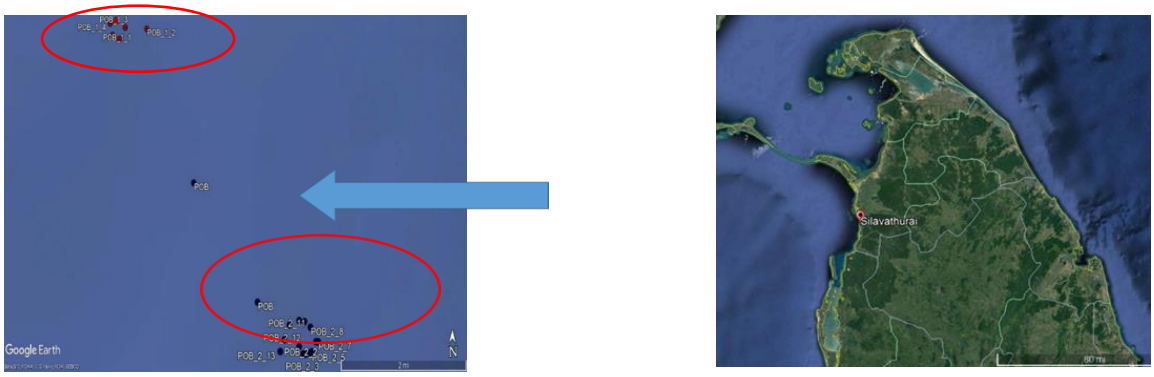


Figure 3.4-4 Distribution of identified pearl oyster beds in Gulf of Mannar.

GPS Coordinates of found sea cucumber beds in point 01 and 02

GPS Coordinates of point 01

South to North Coordinates

1) E 79.43.22.62 / N 8.44.40.83 low amount of oysters recorded
2) E 79.43.49.29 / N 8.44.49.29 Samples were taken
3) E 79.43. 18.55 / N 8.44.55.69 Large amount of oysters were recorded , heaps of oysters

South toNorthCoordinates
1) E 79.43.22.62 / N 8.44.40.83 low amount of oysters recorded
2) E 79.43.49.29 / N 8.44.49.29 Samples were taken
3) E 79.43. 18.55 / N 8.44.55.69 Large amount of oysters were recorded , heaps of oysters

East to west coordinates
1) E 79.43.12.63 /N 8.44.53.72
2) E 79.43.15.78 / N 8.44.44.09
3) E 79.43.27.89 / N 8.44.50.41 large amount of oysters recorded

GPS Coordinates of point 02

E 79.46.12.06 / N 8.41.04.86 small size oysters found.
2) E 79.46.15.27 /N 8 .41.00.47 Large amount of oysters found
3) E 79.46.16.58 / N 8.41.00.13
4) E 79.4619.89 / N 8.41.00.75
5) E 79.46.22.47 / N 8.41.01.83
6) E 79.46.26.45 / N 8.41.07.91
7) E 79.46.28.30 / N 8.41.07.81
8) E 79.46.22.15 /N 8.41.16.69
9) E 79.46.17.19 / N 8.41.20.19

identification of culture site in East coast and continue culture trail in North West coast

Identified as a suitable site during season and off season period. According to the discussion with community Kunithive lagoon area selected as a possible site for pearl oyster culture. Water samples were taken from 7 sampling stations and depth measurements also taken as to cover the area.

Table 01. Water quality parameters of selected sites

Station	Depth (ft)	Salinity (ppt)	DO (ppm)	O^2 (%)	pH	ORP (mV)	Conductivity (ms)	TDS (ppt)
1	20	32	5.79	74	8.02	-61.4	50.7	32.8
2	11	33	5.66	70.5	8	-60.3	50.3	33.2
3	20	33	5.79	74.5	7.98	-60	50.8	33.5
4	12	32	5.65	72.4	8.01	-61	50.8	33.4
5	24.5	33	5.62	71.8	8	-60.6	50.4	33.3
6	15	33	5.41	6.75	7.99	-59.9	50.9	33.5
7	30	33	5.68	6.83	7.96	-57.6	50.6	33.3

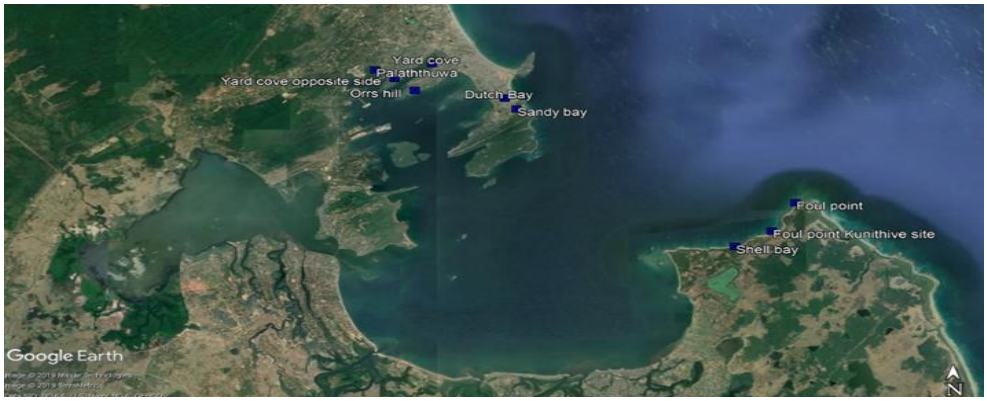


Figure 3.4-5 Inspected sites during the observation field trip in

Sites in Walleippadu deep trenched sea cucumber farms

Wallippadu area along the sea cucumber farms located on deep trenches in coral garden. Depth was recorded as 12-17 feet and salinity was 33ppt.

Figure 3.4-6 Sampling sites at Kunithive site (Identified as more suitable site with compared to inspected sites)

The most important factor as wave action, there were very small wave action and easy to launch raft.

Poaching of Pearl oysters may be the possible effect during the long culture period, this can solve easily because every farm secured by watcher's day and nights.

Water samples were drawn by marked trenches and assessed for other chemical parameters.

Community based pearl oyster farming programme can be easily start with sea cucumber farmers. Pearl oyster spats can be easily transport from Silawathura area during 2-3 hours' period.

800 Nos of mature Pearl oyster samples drawn from Silawathura sea area and stocked at Kiranchi in end of February 2020

Samples were stocked in plastic box until transported safely to coast, samples were covered using wet gunny bags to increase moisture content and maintained liveness.

Sample sizes were recorded shell height, shell length, shell thickness and weight parameters

Table 3.4-1 Morphological parameters of stocked mature oysters

	Shell height (mm)	Shell length (mm)	Shell thickness (mm)	Weight (g)
25/02/2020	46.97± 4.30	37.55 ± 4.30	16.15 ± 2.00	14.62± 3.28
03/07/2020	48.75 ± 2.38	39 ± 3.22	19.05 ± 1.46	18.30± 3.51
18/08/2020	49.60 ± 2.72	39.75 ± 3.47	20.05 ± 1.53	19.35 ± 3.70
20/09/2020	50.01± 3.21	40.02 ± 2.35	20.21 ± 1.65	20.26 ± 2.31
19/10/2020	50.21 ± 2.54	40.10 ± 1.65	20.34 ± 2.10	21.10.± 1.36
23/11/2020	51.01± 2.31	40.92 ± 2.20	20.65 ± 1.64	21.56 ± 2.24

Pearl oyster samples were cultured in perforated plastic bucket structure and net structure to facilitate growth rate. Culture structures were tied to floating rafts

510 Nos of pearl oysters remaining live, according to observations after five months 63.75% of pearl oyster's growth well compare with initial stock.

One oyster raft damaged due to poaching of plastic buckets which used to float ability. Watcher of the sea cucumber farm recovered oyster structures. Because of that we changed floating aids to rig foam buoys

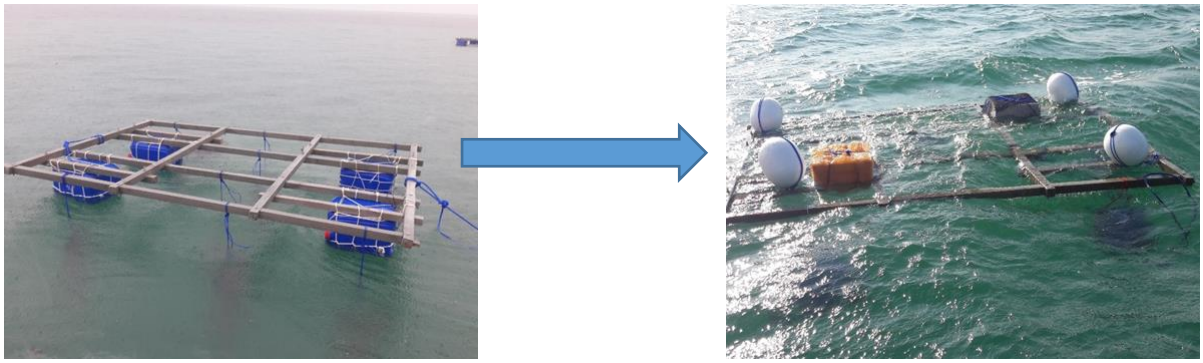


Figure 3.4-7 Plate 07: Convert floating aids to rigifoam buoys

The most important fact that we observed spats in culture structures though we stocked mature oysters in February.

106 Nos of pearl oyster spats were separated and stocked in separate plastic culture box for further culture, 20.78% compare with retained mature oysters.

Table 3.4-2 Morphological parameters of stocked oyster spats

	Shell height (mm)	Shell length (mm)	Shell thickness (mm)	Weight (g)
25/02/2020	23.20 ± 3.50	21.80 ± 3.21	4.73 ± 1.57	2.06 ± 1.33
03/07/2020	23.99 ± 2.35	22.24 ± 2.35	5.01 ± 1.32	3.24 ± 1.34
18/08/2020	24.56 ± 1.35	23.11 ± 3.12	5.85 ± 2.01	4.01 ± 2.01
20/09/2020	25.01 ± 1.54	23.87 ± 1.32	6.10 ± 1.54	5.11 ± 2.11
19/10/2020	25.42 ± 2.34	24.21 ± 2.41	6.85 ± 2.14	6.05 ± 1.54
23/11/2020	26.01 ± 1.67	24.87 ± 1.32	7.03 ± 2.11	6.74 ± 2.51





Plate 08: Figure 3.4-8 Pearl oyster spats after six month of culture period

According to the experimental raft it was recommended floating raft for pearl oyster culture in Kiranchi. Rack culture is nor recommended due to more than 20 feet's depth of restocking place. Initial development of floating raft we used hollow 20L plastic buckets, it gave good floating ability against suspended stocked oyster culture structures. Due to poaching of this baskets we changed floating aids as rigifoam buoys. Nylon net structure used to stock mature oysters due to easy handling, space and easy water movement. According to observation after five months due to Covid pandemic after five months 63.75% of pearl oyster's growth well compare with initial stock. The most important point observed was found of spats attached to mature oysters and culture structures. When we stocked 800 oysters during February there were no any spat observed. It was predicted that due to change of temperature, transportation stress and depth may cause stimulation for spawning of mature pearl oysters. According to the instruction and guidance given by International pearl research group specially designed spat attachment materials designed and stocked at Kiranchi. Spats were carefully detached and stocked at plastic box structures for further growth under protection of external predators.




Figure 3.4-9. Newly developed spat attachment martials by using coir ropes and pearl culture structures

Formation of pearl oyster research group

With the experts in the field of pearl oyster culture in New Zealand and Australia formed an international knowledge sharing group to uplift the pearl culture in Sri Lanka
As the first step there were conducted some zoom meetings to collect background information about

- History of pearl industry in Sri Lanka
- Existing pearl beds in North Western sea
- Proper identification of captured pearl oyster species
- Identification of suitable locations to initiate community based pearl oyster culture
- Further development of pearl oyster culture as commercially

Distinguish committee members

Dr Palitha Kithsiri (NARA) Dr Vasantha Pahalawaththaarachchi (NARA)
Dr Dileepa De Croos (Wayumba University) Prof Dean Jerry – JCU
Dr Kyall Zenger – JCU Prof Paul McShane - JCU
Dr Beatrice Manel Dias-Wanigasekera (Massey University)

NARA's requirements to develop pearl culture in Sri Lanka

The following were identified as priorities:

- Spat collection techniques – Size selection, transportation, spat collector design, materials and technology, rearing, hatchery techniques
- Site selection and parameters (e.g. Water quality, etc)
- Management of rafts and culture environment, health and monitoring (biofouling, parasites, etc)
- Seeding equipment, techniques, post -operative care
- Under the proper identification of captured pearl oyster species
- 10 Nos of samples were send on 15/08/2020 to James Cook University Australia by NARA research team to species identification

On behalf of the pearl research group identification, tests are being carried out by Prof. Dean Jerry, Aquaculture Genetics Program Leader James Cook University Australia.

Constraints:

Covid -2019 Panemic acted as the major killing factor of this year because due to prolong curfew from mid of March to June and October Sampling and underwater survey of pearl oyster bed at Silawathura stopped. The monthly data recording and morphological sampling of stocked pearl oyster samples at suspended floating rafts at Kiranchi. Security issue raised by community based farmers because the poaching of rafts and oysters happened therefore responsibility of security of raft handed over to sea cucumber farmer. Nearly 20% mortality was observed after one month in deposited culture structures, transportation stress may be happened, during the next year project transportation process should be developed.

Output:

Built up awareness among fishing communities, and NARA on community-based pearl oyster culture and potential of culturing pearl oysters in Kiranchi.

Identified of Natural pearl oyster stocks, live samples were taken for species identification by JCU, Australia

Preparation of modified floating rafts and stocked of pearl oyster spats for growth

Outcome:

Proper stock analysis will be carried out to identify existing stock. Location maps already prepared and samples drawn out for identification process. Expert group of pearl research provided guidance for novel initiatives ex, newly developed spat attachment material. This project was important because it kept first step on pearl oyster mariculture in Sri Lanka.

Recommendation:

More samples should draw and stocked for better culture practice. Local fisher folks should aware about importance of pearl oyster mariculture in future. Local culture should successful to start commercial culture of pearl oysters.

Financial Allocation (Rs): 382,000.00

Financial progress (%): 100 Physical Progress (%): 65

3.5 Establishment of gene pool of Kappaphycus alavarzii (Doty) strains in relation to cope with different environmental conditions.

Responsible Officer(s) : J.S. Jayanatha, Vasantha Pahalawathaarchchi

Introduction:

Kappaphycus alvarezii (previously *Eucheuma cottoni*) and the trade name cottonii is one of the most commercially important species which is being culture by many South- East Asian countries. So far private public partnership project of cottoni farming has become successful generating livelihood for more than 200 costal dwellers in the Northern coast. This species of seaweed is cultivated for extraction of carrageenan, and semi refine carrageenan and other compounds used in confectionery and in other industries. South-east Asia is one of the largest producers of carrageenan through extensive cultivation of marine algae. However it has been noted that deterioration of quality of seeds due to continues use of same seed stock. Apart from that it appears that global cottoni seaweed production increases are due to increased number of farmers, not an increase in per farmer production as brought about by technological advances. Hence in order to improve per farmer productivity and raw material quality it should be considered farm systems, farm ecology and crop improvement. Hence under the study purpose it is suggested to use spores/ sporeling cultivation in order to increase the quality of seed stock. Increasing the quality of extract through superior post-harvest handling and strain improvement should be achieved

As in other types of aquaculture/agriculture, monsoons or seasonal events can exert major environmental changes on a farming site. Hence it is also suggested to study the seasonal patterns of growth and carrageenan yields in the prevailing culture systems. Production and processing of these species have become a highly valuable and profitable livelihood activity in many countries. Following verities are mainly cultured in tropical countries, *K. alvarezii* strain Tambalang -green and brown, *K.alvarezii* strain Moumere- green and brown. However, to be sustained our culture and production, identification of exact varieties using genetic sequencing is main target.

Objectives:

Maintain seed bank to carter to community base culture requirements.
Introduced seeds in different locations to identify changes in echo morphological changes in *K. alverazii.*
Gene sequencing for verification of varieties exist in Sri Lanka.

Activities carried out (Methodology)

Following culture types were used,

- Mono-lines
- Multiple lines
- Attached to the wooden poles demarcated area

Sites selections

Sites selection was conducted base on following criteria, such as, culture sites water quality, access to the sites and fresh water influx.

Sites- Keerikuda 1-3, Walaipadu Kiranchi and Kokkupadayan. 50*50m extent was demarcated by using wooden poles and 3mm rope introduced 20cm distance each rope. The seed introduced as 100g propergules per nodes and 650Kg total seeds were introduced to 1 acre premises. Water quality and growth data were collected in every 3weeks, analysis were conducted for following parameters, nitrate concentration, phosphate concentration. Spectrophotometer methods was used to analysis content of Nitrate and Phosphate concentration in water samples.

SST and salinity wee measured using portable meters and SRC and CR extraction were done in IPHT laboratory. Weight increment of seaweed. Nitrate, Phospate concentration, Surface water tem, SD and gel strength (IPHT)

Growth Increments Determinations-

SGR = {(Wt/W0)1/t -1}×100%

Where: SGR = specific growth rate (%/day), Wt = final weight (g), W0 = average initial weight (g), t = length of cultivation (days).

Parameters	
Morphology	Colour variations
	Size
	Branches type
Chemical content	Carrageenan content
Genetics variation	Molecular variations
Water quality	Nitrate concentrations, phosphate concentration

Results

Ecotypes in different locations- *K.alverazii* eco-morphologically changes were recorded in different locations. The well growth and sharp ended tips contained varieties were recorded from Kokkupadayan and Sothern region. However, light color brown and green propergules were recorded in Keerikuda site during the August, that time SST was recorded higher than usual time(34).

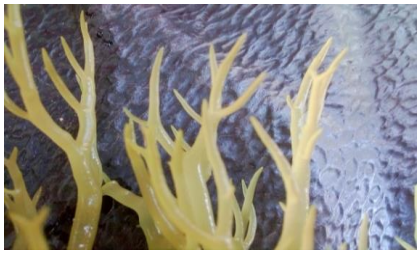


Figure 3.5-1 Different ecotypes in *K. alverazii (green and brown)*

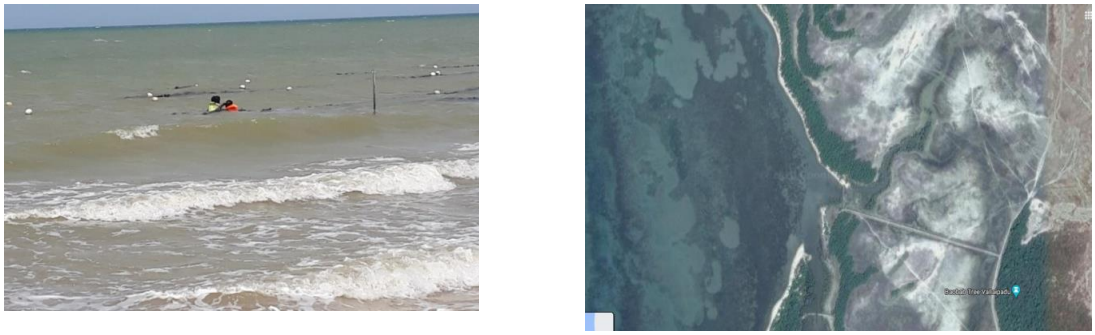


Figure 3.5-2Walaipadu and Kokkupadayan culture sites

The *K. alverazii* seeds were selected in several locations, their morphology also different in location to location. The suitability of seed depend on their growth and number of tips in propergules. The highest propergules number were recorded from Kokkupadayana area, which is dark brown and hard tips consisted. Keerikuda area has highest changes of ecotypes morphology due to the shallowness and SST temperature; the shallowness depend on tidal variation in particular area. According to SST data there was high temperature in water and it was effected on changes of their ecotypes/Eco morphology. In this area propergules were tiny and thin light in green and brown colour.

Table 3.5-1 Ecotypes changes in different locations from Mannar Region.

Locations	Species	Remarks
Keerikuda-1	Green brown	Sharp ended, slightly dark
Keerikuda2	Green Brawn	
Keerikuda 3	Green brown	Light color,
Waleipadu	Green brown	Light color rather than previous
Kokkupadayan	Greenbrown	Thallus color whitish brawn, hard

Phospate concetrations also changes in diffrent locations, the highest concentration was recorded in Keerkuda site1. It‘s similar with Nitrate concentration in that site. The highest conectration was recorded from Keerikuda site1, reveals that dry fish proceesing and their offles are released to the shalow area in this location.

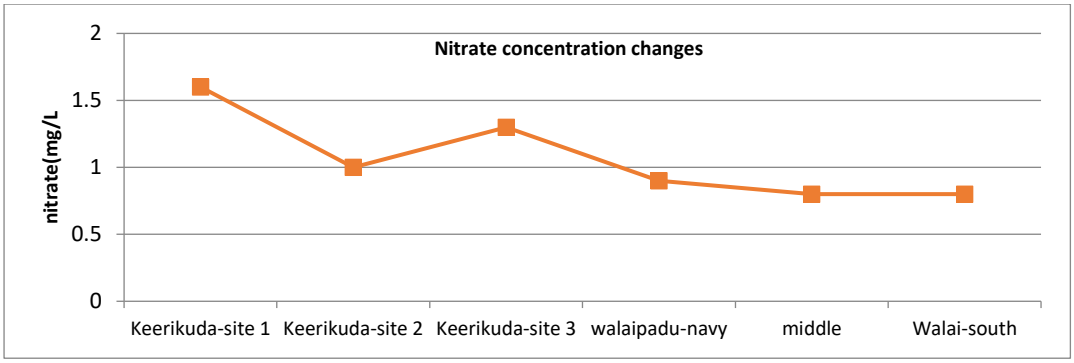


Figure 3.5-3 Nitarte concentration in different locations.

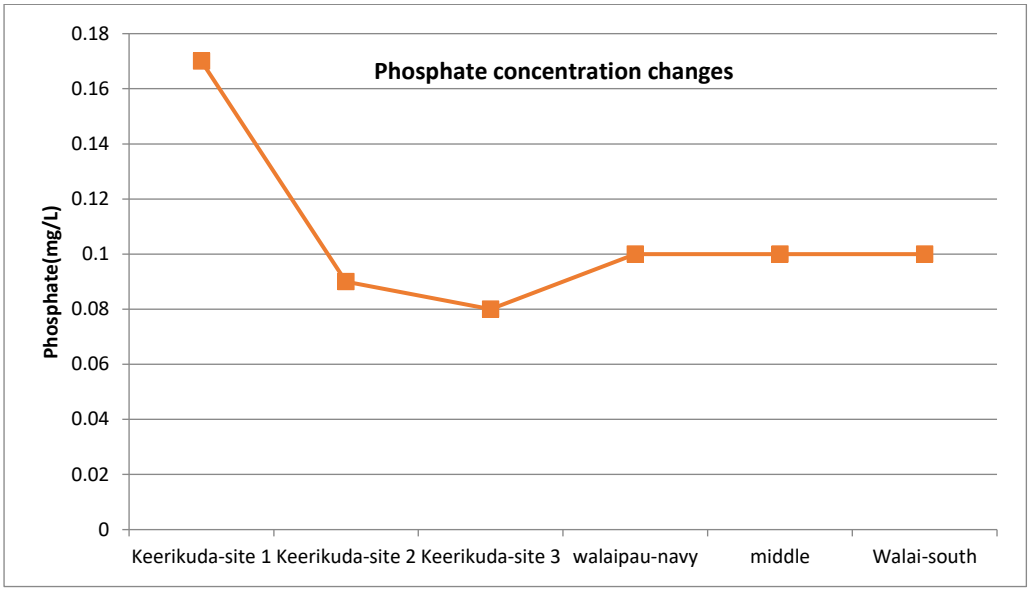


Figure 3.5-4 Phospate concentration in different locations.

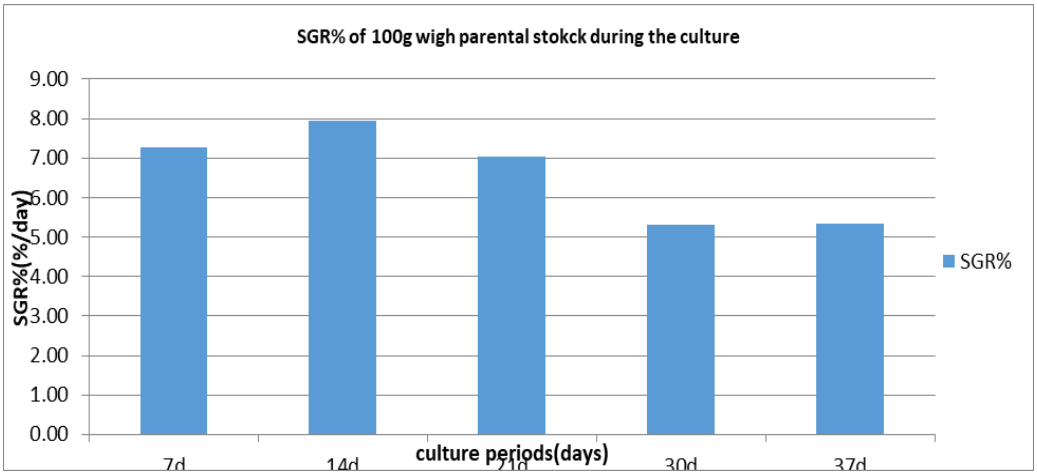


Figure 3.5-5 Specific growth rates (SGR%) during the culture periods in mono-lines in Kudawella area from January-March in 2020.

The high growth rates was recorded during the fist two weeks in inserted bunches, when the growing inserted propergules the self shading effect has increased and growth per day(SGR%) was dramertically decreased.

Table 3.5-2 Properties of SRC from *K. alvarezii* /culture site-Mannar Region

Parameters	SRC(sun dried)
Dry yield	96.89
Wet yield	15.3
pH	8.94
Hardness(gel strength g/cm^2	1159
Gumminess(g)	850
Chewiness	79.65
Moister (%)	8.3
Ash (%)	33
Crude protein (%)	2.9
Crude fat (%)	0.29
Total Carbohydrate (%)	54.54
Colour	whitish yellow

The SRC was extracted from *K.alverazii* from Mannar region, dry yiled was 96.9% and gel strentgh was 1159g/cm^2 , this properties are similar with other SRC extrcation from commercial scale companies.

Conclusions

The gel strenth is suitable to ptodcued commercial scalle prodiuution from K. Alverazii with KOH extraction. To get high economic value from seaweed culture; extraction process introdued to the commercial scale pilot project is more appropreate our production. The direct sea is most suitable place for tye culture; which area may have enough mixing and other environmental conditions to effective growth.

Recommendations

The Ice-Ice disease on *K. alvarezii* can be controlled by using a combination of Iodine (1.5 ppm for 15 minutes) and Ciprofloxacin (2 ppm) it getting severe. Ephyphyts should be clean and remove every week to get good quality seaweed.

Outputs & outcomes

- Increased farmers in engaged seaweed farming.
- Introduced new techniques to established mass culture sites.
- Optimized SRC quality in Mannar region cultured seaweed.
- Increased livelihoods opportunity among community.
- Strengthening sustainable resources uses potential and increased income among the community.

Constraints:

K. alvarezii green (A) and *K. alvarezii* brown (B), The Ice-Ice disease can be occurred extreme weather and other bad environmental conditions.

Tip nipping-it was recorded when growing tips are bitten off. In the plant at right all tips have been nipped buy new ones are growing back. Tip nipping is commonly seen and is often attributed to rabbit fish and juvenile surgeon fish or parrot fish.

Total damage-

It was recorded in all sites when growing seeds without net materials to cover. All tips grazer by the herbivores fish.

Financial Allocation (Rs): 387,000.00

Financial progress (%): 100 Physical Progress (%):90

3.6 Enhancing mangrove crab (Scylla serrata) aquaculture in Sri Lanka through better feed and health management with special reference to popularize the crab farming industry

Officers Responsible : M. G. I. S. Parakrama, A. D.W. R. Rajapakshe, P.P. M. Heenatigala

Introduction:

Scylla serrata, is a very popular crab species because of its size, meat quality, high price and export potential. Natural stock of the crabs in the country is decreasing drastically as the fishing increasing due to the high demand in the export/ local market. Also, people use wild collected water crabs (moulted crabs) for fattening purposes and getting quick income instead of culturing farm produced crablets.

However, recently emerged crab hatcheries are now functioning and the availability of seed is no more a problem, appropriate formulated feed for the culture practice are the most important issue for the development and propagation of crab culture industry in Sri Lanka. Further, farming of hatchery produced crabs can be a good solution for the proper management of natural stocks in Sri Lanka. As the use of trash fish is the traditional method for feeding crabs up to harvesting stage and the availability of trash fish being a limiting factor due to its seasonal changes, an economically profitable nutritious feed is a timely need for the enhancement/ development of the new field. As the imported manufactured feed cost is the highest operating cost in semi-intensive aquaculture practices, the lower profit being the limitation to the development to the industry. Accordingly introduction of economically feasible, good quality nutritious feed for crab culture is an urgent option to enhance the crab production in Sri Lanka. Also the information and precaution measures of the possible disease problems in the crab culture practices will be a timely need for the better management of the system.

Objectives:

- To introduce a quality feed for crab farming
- To identify the disease problems in crab culture systems

Activities carried out

- Preparation and renovation of the vertical farming boxes of private crab farmer at Veyangoda area.
- Procurement of water crabs
- Feed formulation and preparation
- Proximate analysis of feed samples
- Individual water crabs are stocked in 60 vertical crab boxes/ rooms using 02 experimental feeds compared to trash fish as control feed

- Sampling and data collection for water quality parameters, growth performances, survival rate.

Conclusions

Before the covid -19 lock down period, the crabs were accepting the formulated feed and simply growing healthy. Few mortalities due to molt death syndrome were observed.

Outputs & outcomes

Research collapsed before terminate due to lock down period.

Constraints:

Research collapsed due to corona lock down at Veyangoda, Gampaha and Colombo areas. Procurement completed

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Financial Allocation (Rs): 235,000.00

Financial progress (%): 100 Physical Progress (%): 58

3.7 Biofloc Technology as an Integral Approach to Enhance Production Performance of ornamental fish Guppy (Poecilia reticulata) farming

Officers responsible : E.D.M. Epasinghe

Budget (Rs.) :0.992 M

Introduction

The global trade of the ornamental fish industry is increasing rapidly, at around 6% annually. In the aquaculture sector, ornamental fish breeding, culture and trade provide excellent opportunities as a non–food fishery activity for employment and income generation (Panigrahi*et al*., 2009). The guppy is considered to be the most popular aquarium fish and three of the top 10 species in the world ornamental fish trade (Singh, 2005).

Biofloc is aggregated (flocs) of algae, bacteria, protozoans, and other kinds of particulate organic matter such as faeces and uneaten feed. In biofloc technology, minimum water discharge and reuse of water prevent environment degradation and convert such a system in a real "environmentally friendly system" with a "green" approach. By adding carbohydrates to the tank, heterotrophic bacterial growth is stimulated and nitrogen uptake through the production of microbial proteins (Crab *et al*., 2012).

Objective/s:

- Investigating water quality parameters of the BFT system
- Investigating reproductive performance of female guppies (*Poecilia reticulata*) in BFT
- Investigating larvae performance of guppies (*Poecilia reticulata*) in BFT
- Investigating stress resistance through the salinity stress and starvation tolerance of male guppies and fry stages in BFT
- Investigating stress resistance of male guppies for packing stress in a export packing system (Lim, *et al.*, 2003) and effect on dead on arrival during 7 days (DA7) in BFT

Methodology:

Location

The experiment was conducted in Inland Aquatic Resources and Aquaculture Division (IARAD), National Aquatic Resources Research and Development Agency (NARA), Colombo.

Experimental Setup

A total of 24, rectangular tanks with a capacity of 200 L was placed providing indoor conditions and total culture period was 82 day

Treatments

Experiment tanks were randomly assigned to seven treatments. Biofloc was formed with added rice bran (RB), molasses (MOL), wheat flour (WF), rice bran-molasses (RB-MOL), molasses-wheat flour (MOL-WF) or rice bran-wheat flour (RB-WF). Carbon sources were added to the tank daily at 3.30 p.m. and it was dissolved in the water. The control was set-up without adding any carbon source. The C/N ratio was maintained at 20 as described by Emerencian*oet al.,* (2017). Each treatment consisted of three replicates.

Fish Stocking and Maintenance

Twenty-one days old male Red blonde guppy juveniles with a mean body weight 1.3 ± 0.1 g and standard length 1.5 ± 0.1 cm were used in the study. They were acclimatized for 1 week prior to the experiment. Fish was stocked as 10 fish per cubic foot for each treatment. Aeration was provided to the experiment tanks using an air blower throughout the experiment. Commercial feed (with crude protein = 56%, crude fat = 15%, crude fibre = 0.1%) was provided daily in each tank at 3% of the total body mass of the stocked fish. Daily feed ration was split into two equal portions and was given 2 times per day at 10.00 a.m. and 3.00 p.m. Total culture period was two months.

Data Collection and Calculations

Fish Growth and Feed Conversion Ratio

The average body weight and length of guppy were measured in 14-days intervals during the cultural period. Ten fish of male guppy were randomly collected from each tank and the body weight was measured using an electrical balance (OHAUS CORP, PA4102C, Germany) and the standard body length was measured using a ruler. The feed was measured prior to offer using electrical balance according to the body weight of fish in each tank. The number of dead fish was counted during the culture period. The feed conversion ratio (FCR), specific growth rate (SGR), weight gain (WG), survival rate (SR) and mortality rate (MR) were calculated according to the following formulas reported by Rono *et al.*, (2018).

$$\text{FCR} = \frac{\text{Weight of given feed(g)}}{\text{Live weight gain(g)}}$$

$$\text{SGR} = \frac{(\text{In fina body weight} - \text{In initial body weight})}{(\text{Number of days of experiment})} \times 100$$

$$\text{WG(g)} = 100 \times \frac{\left(\text{Final body weight(g)} - \text{Initial body weight(g)}\right)}{\left(\text{Initial body weight(g)}\right)}$$

$$\text{Survival rate}(\%) = \frac{(\text{Total number of fish surviving})}{(\text{Total number of fish stocked})} \times 100$$

$$\text{Mortality rate } (\%) = \frac{\text{Number of fish that died during the experiment}}{\text{Number of fish at the beginning of the experiment}} \times 100$$

Water Quality Parameters

Water quality parameters such as temperature, dissolved oxygen (DO) and pH were measured *in situ* each morning at 9.00 a.m. Temperature and pH were measured using a pH meter (EUTECH instrument, Singapore) and DO was measured using a DO meter. (HACH, HQ30d, France). Total suspended solids (TSS) and floc volume (FV) were measured weekly using the Filter method and Imhoff cone method, respectively (Annexure I). Total ammonia nitrogen (TAN) was measured weekly using powder pillows method (Annexure II) as described by NARA (2018) using a spectrophotometer (DR 6000, HACH, Germany).

Results and discussion:

a.Effect of Different Sources of Carbon on Growth Performances of Male Guppy

The significantly lowest *(p>0.05)* WG of fish was observed in control and WG was significantly higher in carbon supplied treatments. Further, the use of carbon sources resulted significantly *(p<0.05)* lower FCR in fish cultured with carbon sources compared to control tank. It is well documented that fish culture in the carbon supplemented biofloc system increase utilization of protein and convert most of the diet to the body mass (Kumar et al., 2014). (Table 3.7-1)

Table 3.7-2 Growth variables of male guppy reared in different sources of carbon

Growth parameter	Carbon source*							SE
	CON	MOL	RPP	RPPMOL	RPPWF	WF	WFMOL	
Weight at 7th week	0.31^{a}	0.62^{b}	0.50^{b}	0.50^{b}	0.55^{b}	0.55^{b}	0.61^{b}	0.07
Length at 7th week	1.74^{a}	3.07^{b}	3.00^{b}	3.00^{b}	3.01^{b}	3.05^{b}	3.05^{b}	0.32
WG (G)	113.84^{a}	633.71^{b}	403.67^{b}	402.16^{b}	426.31^{b}	445.17^{b}	451.35^{b}	50.10
SGR (%)	1.07^{a}	2.03^{b}	1.70^{b}	1.72^{b}	2.03^{b}	2.04^{b}	2.15^{b}	0.17
FCR	2.13^{a}	1.30^{b}	1.31^{b}	1.50^{b}	1.41^{b}	1.83^{b}	1.61^{b}	0.15

$^{a, b}$ means within the same row with different superscripts are significantly different *(p<0.05)*

*CON – control; MOL – molasses; RPP – rice polish powder; RPPMOL – rice polish powder-molasses; RPPWF – rice polish powder-wheat flour; WF – wheat flour; WFMOL – wheat flour-molasses

b.Water Quality Parameters

Table 2 shows the water quality parameters which were measured before adding the treatments and after adding the treatments on 1st carbon calculation and 2ndcarbon calculation in cultured tanks which had different sources of carbon. There was no significant difference *(p>0.05)* in pH, dissolved oxygen (DO) and temperature in water before adding treatments. However, DO and pH were significantly differed*(p<0.05)* after adding different sources of carbon to form the bioflocs. Dissolved oxygen concentration significantly different*(p<0.05)* when forming biofloc, which might be attributed to higher total heterotrophic bacteria in the biofloc treatment which utilized DO for their microbial metabolism. There was a significant difference *(p<0.05)* in TAN, FV and TSS among the treatment (Table 3.2). Total ammonia nitrogen (2.35 ± 0.19 mgL^{-1}) in the control was significantly higher (*p<0.05)* compared to water supplied with other carbon sources ($0.41 \pm 0.19 – 1.68 \pm 0.19$ mgL^{-1}).Ekasari *et al*., (2015) pointed out that the addition of carbohydrate reduces the need for dietary protein while reducing total ammonia nitrogen concentration in the fish rearing unites. However, in the present experiment, WF (1.68 ± 0.19 mgL^{-1}) had higher mean value for TAN than other sources of carbon ($0.47 \pm 0.19 – 1.51 \pm 0.19$ mgL^{-1}).Although WF was effective for the growth performance, it cannot be recommended as a good source to maintain the water quality in biofloc system.There were significant differences *(p>0.05)* in survival and mortality rates of fish reared in different sources of carbon. The significantly lower *(p>0.05)* survival rate of fish was recorded withRPP (31.14%) treatment compared to other treatments (53 – 95%). It may be due to poor water quality in RPP treated culture tanks.

Table 3.7-3 Water quality parameters of male guppy reared in different source of carbon

Parameters	Carbon source*							SE
	CON	MOL	RPP	RPPMOL	RPPWF	WF	WFMOL	
DO								
Before*	8.94	8.91	8.87	8.92	8.88	8.93	8.92	0.03
After**	8.78[a]	8.50[b]	8.55[b]	8.53[b]	8.58[b]	8.55[b]	8.57[b]	0.05
After***	8.58[a]	8.17[b]	8.34[b]	8.28[b]	8.20[b]	8.33[b]	8.22[b]	0.17
pH								
Before*	6.54	6.41	6.51	6.6	6.54	6.52	6.54	0.60
After**	6.60[a]	6.88[b]	6.88[b]	6.87[b]	6.86[b]	6.89[b]	6.86[b]	0.02
After***	6.12[a]	6.80[b]	6.82[b]	6.83[b]	6.80[b]	6.81[a]	6.80[b]	0.17
Temperature								
Before*	26.23	26.74	26.67	26.72	26.66	26.63	26.58	0.13
After**	27.00	27.00	27.00	27.10	27.00	27.00	27.00	0.12
After***	27.80	27.15	27.15	27.60	27.21	27.22	27.17	0.05
TAN mg/L-1	2.35[a]	1.37[b]	0.68[c]	1.51[b]	0.41[c]	1.68[b]	0.47[c]	0.19
FV mg/L-1	0.10[a]	62.00[b]	52.00[b]	50.66[b]	19.17[c]	0.96[a]	31.40[c]	12.49
TSS	19.32[a]	165.53[b]	130.31[c]	114.33[c]	64.52[d]	60.00[d]	72.01[d]	22.00

[a, b, c, d] Means within the same row with different superscripts are significantly different *($p<0.05$)*

Before* = before adding biofloc treatment, After** = after adding biofloc treatment on 1st C calculation, After*** = after adding biofloc treatment on 2nd C calculation

*CON – control; MOL – molasses; RPP – rice polish powder; RPPMOL – rice polish powder-molasses; RPPWF – rice polish powder-wheat flour; WF – wheat flour; WFMOL – wheat flour-molasses

Survival and Mortality Rates of Male Guppy Reared with Different Sources of Carbon

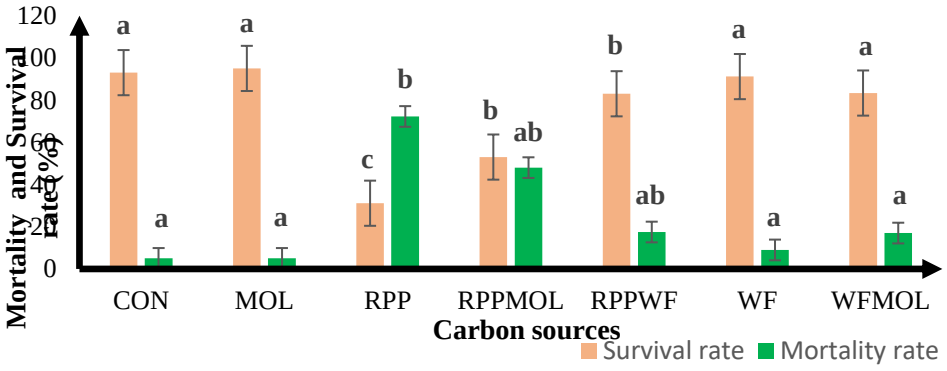


Figure 3.7-1 Survival and mortality rates of male guppy with difference carbon sources

[a, b, c] Means with different superscripts among the treatment for survival and mortality rates are significantly different *($p<0.05$)*

CON – control; MOL – molasses; RPP – rice polish powder; RPPMOL – rice polish powder-molasses; RPPWF – rice polish powder-wheat flour; WF – wheat flour; WFMOL – wheat flour-molasses

There were significant differences*(p>0.05)* in survival and mortality rates of fish reared in different sources of carbon (Figure 4.1).The significantly lower *(p>0.05)*survival rate of fish was recorded with RPP (31.14%) treatment compared to other treatments (53 – 95%). It may be due to poor water quality in RPP treated culture tanks. Because the mortality rate was significantly higher*(p<0.05)* in RPP treated culture tank compared to control, WF and WFMOL (Figure 1).

Conclusion:

Carbon sources supplemented in the biofloc system have the ability to improve the growth performance of male guppy juveniles and reduce the inorganic nitrogen accumulation hence improving water quality. Molasses (MOL) and wheat flour-molasses (WF-MOL) exhibited higher fish growth and survivals as compared to the other sources of carbon. Improved water quality was recorded in MOL and WF-MOL added treatments as compared to the other treatment. This is an indicator that MOL and WF-MOL carbon sources improve growth parameters while maintaining better water quality with a higher survival rate in the male guppy juveniles.

Recommendations:

BFT can successively be adopted to grow guppies without changing water for 60 days.

For the development of bioflocwith different carbon sources, MOL and WF-MOL could be recommended as the suitable and more effective carbohydrate sources which are locally available.

C/N ratio for these carbohydrate sources should be 20; it is advisable to check available total ammonia concentration in the water before adding them in to the water.

Biofloc technology could be implemented in farm level with the modifications of tank system especially for guppies; the water height of the tank should be increased up to 1.5 feet to 2.0 feet in order to keeping suspension of water well and continuous aeration should be provided throughout the culture period. This study is re confirmed the 2019 findings and suitability of same carbon sources which had used in the 2019 biofloc study.

Output:

Introduced biofloc technology to Ornamental Fish Breeding and Training Center managed under National Aquaculture Development Authority (NAQDA) located Rambadagalla in Kurunegala district.

Outcome:

Enhanced sustainability of ornamental aquaculture industry in Sri Lanka is with novel aquaculture technologies.

Constraints:

In the first quarter of the year this study was initiated however with the Covid 19 pandemic situation in the country we had to terminate the studies. Therefore, expected outputs were achieved partly, especially we did not receive ordered chemicals and some of the necessary equipment on the right time. Further, the latter part of the study could not continue because no one in the indoor research facility and responsible officer could not enter to the NARA premises due to above said matters.

Financial Allocation (Rs): 1,350,000.00

Financial progress (%): 99 Physical Progress (%): 64

3.8 Maintenance of endemic fish captivity breeding and display section

Note: Originally it was proposed to continue 2019 research project to study "Climate change impacts assessment on seven threatened endemic fish species, identification of their vulnerable ecosystems and

develop conservation strategies". Due to COVID condition the project was identified as an unfeasible project as there are difficulties to carry out relevant field based work. Then it was changed as above.

Responsible Officer(s) **:** Ramani Shirantha

Introduction:

NARA as a national body has to maintain the collection of endemic fishes for education and awareness purposes and also need to study on endangered fish species and ecosystem to updat the information on them in order to make suitable recommendation for the relevant authorities wherever necessary. Conduct conservation strategy development trails, experiment on rare endemic with breeding technology, quality improvement and aquarium condition development for research and awareness purposes and technology transferring are the key activities.

Objectives:

Continuous rearing and of rare and economically import endemic fishes

Maintaining and upgrading of the indoor aquarium.

Methodology

Due to COVID pandemic scenario the present research project had to be limited only to brooder collection from Kitulgala -Yatiyantota, Bambarawana, Morawaka- Akuressa, Ruwanwella, Gileemale and Galapitamada and rearing them at NARA. In addition to that continous breeding trails on Pethia bandula and P. melanomaculata were done through environment manipulation procedure as usual. Monitoring of the wild population of Systomus asoka in Kitulgala area was performed.

Results

The work was focused to collect brooders form the wild targeting supply quality fish for fish exporter in 2021 as proposed by the line ministry.

The following fish species were collected and now rear at NARA.

Fish species	**No of pairs rare at NARA**
Pethia nigrofaciata	25
Pethia reval	50
Pethia bandula	10
Pethia cumingii	15
Puntius titteya	20
Belontia signata	25
Malpullutta kretseri	10
Raboroides vaterifloris	25
Danio pathirana	25

Outputs & outcomes

- Brooders of nine fish species for captive breeding trails to be done in 2021.
- Developed facilities in indoor aquarium.

- Datasets to be used by relevant ministries for policy decision to conserve and management of threatened fish species and ecosystem thereby increase foreign exchange earns and aquaculture practices.

Constraints:

COVID pandemic condition limited the targeted activities.

Financial Allocation (Rs): 455,000.00

Financial progress (%): 100 Physical Progress (%): 100

3.9 Study the growth performances of selected aquatic macrophytes in aquaponic recirculating system and biotechnological application of Aquatic plants and seaweeds.

Responsible Officer(s) : Dr. K.K.T.Nuwansi, D.M.S.Sugeeshwari,

Dr. V.Pahalawattaarachchi

Introduction:

Aquaponic systems are recirculating aquaculture systems that incorporate the production of plants without soil. It is already cultivated the aquatic plants in hydroponically and less attempts taken in aquaponics. Thus it would be beneficial to find out the possibilities of cultivating aquatic macrophytes as it is a low cost and environmentally friendly technique.

Aquatic plant used in this study is *Anubias barteri* var. *nana ''petite''.* It is a man-made cultivated variety originally developed from *Anubias barteri* var. *nana* and has great aquascaping potential for every aquarium. As it is soilless culture technique it can compete well even in the export market for higher price due to the absence with soil borne pathogens.

When the hydroponics systems combine with fish tanks and allow the system to recirculate it will produce duel products at the end of the culture period. It will help to reduce the cost of artificial fertilizer and at the end of the culture period farmer would be able to gain two varieties of harvests instead of one. Also, this type of production systems are environmentally friendly and leads to sustainable aquaculture production which having minimum environmental impacts.

As the ornamental aquatic plant industry has focused to the export market, it is very much important to get large number of plant production. Development of the new traits is also very much important to cope up with the international market. Therefore, by applying various biotechnological methods are very important to develop new traits for valuable ornamental aquatic plants.

This could be achieved by using micro propagation techniques. Hence plant tissue culture laboratory of The National Aquatic Resources Research and Development Agency, has undertake various research to develop protocol for the selected aquatic plants and conducting mass production of aquatic plants to the plant house of the NARA.

Objectives:

To develop techniques to increase the production of Aquaponically produce aquatic microphytes .

To develop the technique to get high production of tissue cultured aquatic plants and marine macrophytes.

Activities carried out (Methodology)

Activity 1- Study the growth performances of selected aquatic macrophytes in aquaponic recirculating system

Prior to the main study of aquaponics, two preliminary studies were carried out to find out the nutrient concentration of fertilizer and suitable substrate media.

Study the effect of nutrient concentration for the growth performances of *Anubias barteri* var. *nana* (pertite)

Sixty-day experiment was conducted to evaluate the growth performances of *A. barteri* var. *nana* '*pertite*' in a hydroponic system using different nutrient concentrations of Albert's solution such as 0.005 (T1) ,0.01(T2),0.02(T3),0.05(T4) and each treatment had three replicates. Two months old, hardened healthy tissue cultured plants were employed in the study. Albert's solution of 0.005 mg/L was used as the fertilizer. As the growth parameters plant wet weight was taken to assess the plant growth at the significance level of $P < 0.05$. Sampling and fertilization were done fortnightly.

Study the effect of substrate media for the growth performances of *Anubias barteri* var. *nana* (pertite)

Sixty-day experiment was conducted to evaluate the growth performances of *A. barteri* var. *nana* '*pertite*' in a hydroponic system using different types of locally available growing media: crushed stones (T1), pieces of coconut husks (T2), clay stones (T3) and wood scrapings (T4) and each treatment had three replicates. Two months old, hardened healthy tissue cultured plants were employed in the study. Albert's solution of 0.005 mg/L was used as the fertilizer. The growth parameters *viz.* plant weight, numbers of leaves, leaf length, leaf width, length of the rhizome, root length were taken to assess the plant growth at the significance level of $P < 0.05$. Sampling and fertilization were done fortnightly.

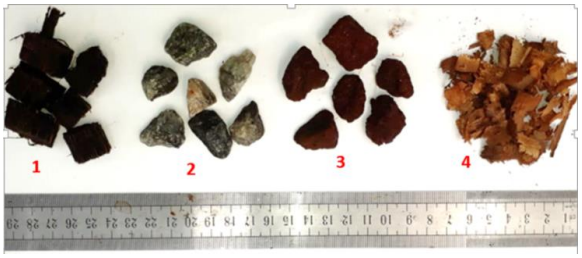


Figure 3.9-1 Different types of substrate media

Activity 2-Biotechnological application of aquatic plants and seaweeds

Development of sterilization protocol for *Aponogeton cryspus* and *A. natans*

The selected explant was seed and it was thoroughly washed with soap. Then all explants were washed with 70% ethanol for 1 minute and then with 4%, 5% and 7% Clorox (Liquid bleach) for 5 minutes. Each treatment consists of 12 replicates. Then the seeds were thoroughly washed with sterilized distilled water three times and each wash was done for 3 minutes. Then the seeds were cultured in liquid Murshige and Skoog medium for 21 days.

Selection of best medium composition for shoot growth of the Seaweed (*Kappaphycus alvarezii)*

After ex plant sterilization, ex plants were culture in sterilized seawater with 4mg/L Benzyl Adenine Purine and 0.5 mg/L Naphthalene Acetic Acid which contain 0.5mg/L albert solution and 1g/L seaweed extract. Aeration and 12-hour photoperiod were provided. Media changed in every 2 days. Each treatment had 3 replicates and culture period was existed for 21 days.

Results

Activity 1- Study the growth performances of selected aquatic macrophytes in aquaponic recirculating system

There were no significant differences between the treatments. But the highest performances given by T1.

Table 3.9-1Plant wet weight with different treatments

Treatment	**plant wet weight(g) (mean±SEM)**
T1	1.42 ± 0.07^{a}
T2	1.39 ± 0.08^{a}
T3	1.26 ± 0.04^{a}
T4	1.30 ± 0.02^{a}

Coconut husks proved to be the best media when considering the plant weight (1.28±0.05 g) followed by wood scrapings (1.21±0.07 g) and there was no significant difference between the two treatments. Clay stones showed the poorest weight gain of the plant (0.8±0.03 g). Coconut husk media showed the highest number of leaves (19.00 ±0.58), leaf length (2.66±0.09 cm), leaf width (1.46 ±0.03 cm) and rhizome length (0.67±0.09 cm). Wood scraping media obtained the maximum root length which was significantly different with other treatments (5.53±0.98 cm).

Table 3.9-2 Growth performance with different treatments

Parameter	**Substrate Media (Treatments)**			
	T1 (n=3) Crushed stones	T2 (n=3) Coconut husks	T3 (n=3) Clay stones	T4 (n=3) Wood scrapings
Plant weight (g)	1.02 ± 0.05^{c}	1.28 ± 0.05^{a}	0.8 ± 0.03^{b}	1.21 ± 0.07^{a}
Number of leaves (number)	17.00 ± 2.08^{ab}	19.00 ± 0.58^{b}	13.33 ± 1.20^{a}	17.00 ± 0.57^{ab}
Leaf length (cm)	2.00 ± 0.11^{a}	2.66 ± 0.09^{b}	2.00 ± 0.06^{a}	2.23 ± 0.12^{a}
Leaf width (cm)	1.26 ± 0.03^{b}	1.46 ± 0.03^{c}	1.10 ± 0.06^{a}	1.30 ± 0.06^{b}
Rhizome length (cm)	0.66 ± 0.00^{b}	0.67 ± 0.09^{b}	0.37 ± 0.07^{a}	0.63 ± 0.03^{b}
Root length (cm)	2.80 ± 0.70^{a}	3.56 ± 0.38^{ab}	2.93 ± 0.81^{a}	5.53 ± 0.98^{b}

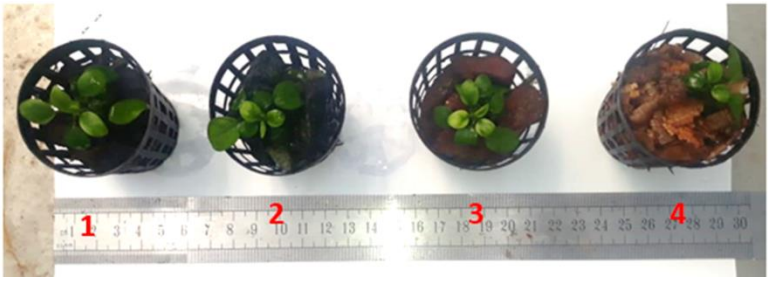


Figure 3.9-2 Plants cultured on different substrates

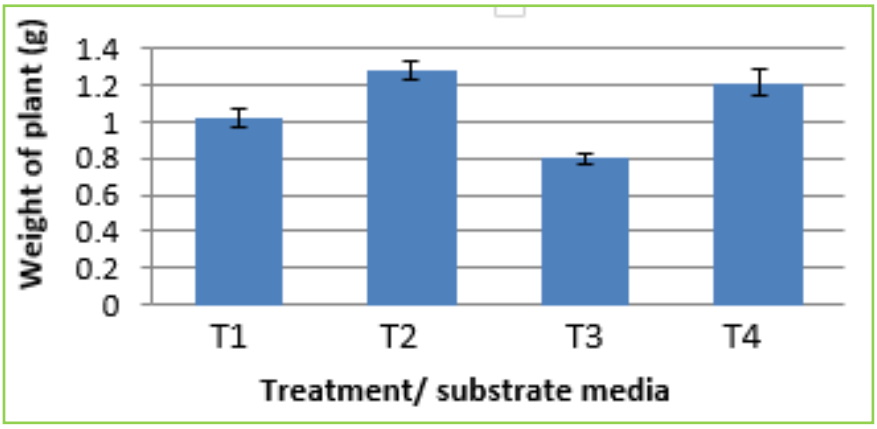


Figure 3.9-3 Growth performance with different treatments

Activity 2- Biotechnological application of aquatic plants and seaweeds

Development of sterilization protocol for *Aponogeton cryspus* and *A. natans*

There was no significant difference between the 3 treatments. But 100 % survival of the ex-plant got from the treatment which has applied 4% Clorox.

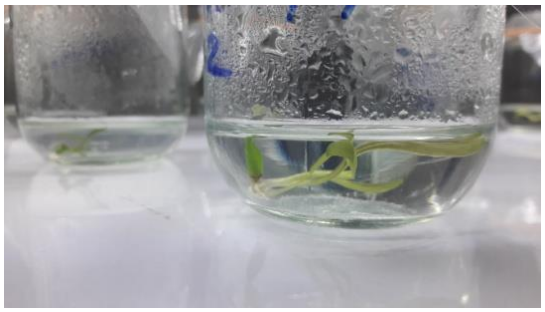


Fig. 3: Suvived ex plant of *Aponogton sp*

Selection of best medium composition for thallus growth of the Seaweed (*Kappaphycus alvarezii)*

The thallus initiation and development has shown only in medium supplemented with 0.5mg/L Albert solution.

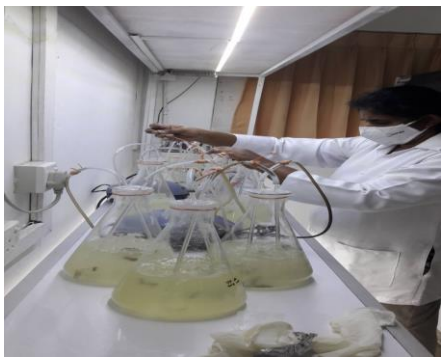


Fig 4: Ex- plant culture of seaweed

Activity 1- Study the growth performances of selected aquatic macrophytes in aquaponic recirculating system

a.Study the effect of nutrient concentration for the growth performances of Anubias barteri var. nana (pertite)

According to the selected concentrations 0.005mg/L is the suitable concentration and Anubias has very low nutrient requirement.

b.Study the effect of substrate media for the growth performances of Anubias barteri var. nana (pertite)

The results of the experiment concluded that the coconut husk media is the most suitable substrate which is a low cost, locally available media for the hydroponic cultivation of *Anubias* spp. and also wood scrapings found to be an effective media when it is available in the environment.

Activity 2-Biotechnological application of aquatic plants and seaweeds

Best medium coposition for thallus rgenaration and thallus growth was sterilized seawater with 4mg/L Benzyl Adenine Purine and 0.5 mg/L Naphthalene Acetic Acid. which contain 0.5mg/L albert solution.

Recommendations

Further studies need to be carried out by using other suitable concentration series and other locally available substrate media.

Outcomes:

Production of *Anubias barteri* var. *nana* (pertite) for community**.**

OutPut:

Development of the culture techniques for better and sustainable aquaculture practices in Sri Lanka.

Constraints:

Due to the lockdown in March 17th most of the aquatic plants were died and continuous research work also affects. Thus some of the research parts couldn't be completed and those parts will be shifted in to year 2021.

Laboratory contamination occurred in month of June. Hence the tissue culture laboratory must be condition to start for the research performance.

Effect for continuous research performance form the situation with Covoid 19 .

Financial Allocation (Rs) :840,000.00

Financial progress (%): 99 Physical Progress (%): 60

3.10 Study on Disease prevalence in ornamental fish and cultured Tilapia.

Responsible Officer(s) : A.D.W.R.Rajapakshe

Introduction:

Tilapia Lake Virus has been emerging disease of wild and farmed Tilapia in many countries including three continents. As the surrounding countries are already affected by this pathogen, Sri Lanka has a great risk to enter this pathogen and destroy the tilapia population. Therefore continuous surveillance and monitoring needed for preventing and control this pathogen.

Diseases are one of the major constrain in ornamental industry. Among these diseases Bacterial, viral and parasitic infections can be found. Parasitism is one of the most impacting problems in aquaculture industry. The effect of parasitism in fish result poor growth /production and the susceptibility to secondaryinfections (Scholz,1999).Most parasitic disease s harm the quality of fish which directly affect s the marketable price of fish. Ornamental industry people raised that metacercaria (Trematodes) and gill flukes problems are severe at present in Sri Lanka.

Therefore attempt will be made to determine the prevalence of metacercaria and gill flukes in most common fresh water ornamental fish for the benefit of ornamental industry

Objectives:

- Reduce the risk of TiLV introduction.
- Understanding the commonly encountered disease conditions in ornamental fishindustry.

Activities carried out (Methodology)

- ✓ Literature survey on prevailing disease condition in Industry.
- ✓ Selected aquaria from Colombo and Gampaha districts.
- ✓ Collected Samples andinformation from each aquaria at monthly intervals (5 fish per
- ✓ each species of Ornamental fish) and Tilapia when informed by NAQDA(for TiLV).
- ✓ Analyzed the samples in the laboratory and identified the parasite microscopically.
- ✓ Conduct experiment in the laboratory for developing the therapeutic measures.
- ✓ For Tilapia Lake virus, clinical and histopathological observations were carried out.
- ✓ Prevalence % was calculated according to the following formula.

- **Prevalence**= No. of Infected fish x **100**

  Total no. of fish examined

Table 3.10-1 No of fish collected from each Aquarium

Month	**Aquarium**	**No of Fish collected**	
		Gold fish	**Carp**
February	Ragama	15	-
	Negombo	04	06
	Wattala	06	06
June	Negombo	05	10
	Wattala	05	05
	Colombo	05	05
July	Ragam	10	05
	Negombo	05	05
	Wattala	05	05
August	Ragama	05	05
	Negombo	06	06
	Wattala	05	05
	Colombo	05	05
September	Ragama	06	03
	Negombo	05	06
	Wattala	05	05

	Colombo	05	05
Total no. of fish		**102**	**87**

Figure 3.10-1 Fish samples from aquarium

Results

Total 102 gold fish and 87 koi carps have been collected throughout the experimental period (Table - 1). Main parasites which were encountered in gold fish and Koicarp were *Centrocestus sp., Trichodina, Dactylogyrus, Gyrodactylus and Ichthyoptherious.*High prevelance% was recorded by Dactylogyrus *and Gyrodactylus* in Negombo Aquarium. Comparing two fish species, infected parasites are higher in Gold fish than Koi carp. Higher no of parasites were recorded in gold fish in Colombo and Negombo aquaria .Less prevalence % of each parasites were recorded in koi carp in Colombo Aquarium (Table 2). *Dactylogyrus, Centrocestus* and *Gyrodactylus* were recorded in each aquaria.

Table 3.10-2 Infected Parasite species & their Prevalence% of Gold fish and Carp in 4 Aquariums

Infected Parasite	**Prevalence% of parasite in Gold fish**				**Prevalence% of parasite in Carp**			
	Ragama	**Negombo**	**Wattala**	**Colombo**	**Ragama**	**Negombo**	**Wattala**	**Colombo**
Centrocestus sp.	63.63	23.80	28.57	14.28	16.66	26.08	38.09	7.14
Trichodina	9.09	47.61	38.09	28.57	ND	17.39	4.76	7.14
Dactylogyrus	27.27	78.57	52.38	35.71	50.0	47.82	4.76	14.28
Gyrodactylus	27.27	64.28	28.57	42.85	8.33	8.69	4.76	7.14
Ichthyoptherious	18.18	28.57	9.52	14.28	8.33	4.34	ND	21.42

ND- Not Detected

Three Tilapia mortality were investigated in Wilachchiya wewa in Anuradapura , Minneriya wewa and Ellewewa in polonnaruwa district. Tilapia fingerlings were collected from Dambulla and Sewanapitiya hatcheries for investigation of TiLV. All the samples are negative for TiLV according to clinically and histopathology.

According to the therapeutic experiments 2g/ l salt is effective for totally eradicating *Trichodina. and Gyrodactylus* (Skin Flukes).

2g/L salt can be use for Controlling *Dactylogyrus* (Gill Flukes) in mild infection. For higher infections 10g/l salt dip is recommended.

Figure 3.10-2 Dual infection with Metacercaria & Gill Flukes and eexperiments in the Quarantine section

Conclusions

- Main parasites which were encountered in gold fish and Koi carps were *Centrocestus sp., Trichodina, Dactylogyrus, Gyrodactylus and Ichthyoptherious.*
- Infected parasites are higher in Gold fish than Koi carp.
- 2g/ l salt can be used effectively for eradicating *Trichodina. and Gyrodactylus* (Skin Flukes).
- 10g/l Salt dip is recommended for eradicating Gill flukes.
- Observed samples are negative for TiLV.

Recommendations

- Salt treatments are effective for illeminating external parasites. Therefore, salt treatments are recommended before selling fish.
- After infection of *Centrocestus* treatments cannot be used as they are in inside the tissues.Problem can be minimized by controlling snails and falling the birds dong.
- Each Tilapia mortalities should be checked for TiLV for reduce the risk of viral infection.

Outputs

- Theraputic measures for erradicating the *Tricodina* and skin flukes.
- Most common external parasites in aquarium fish

outcomes

- No records for TiLV in Sri Lanka.
- Incensement of ornamental fish survival with the knowledge of chemical therapy

Constraints:

Unable to continue the project works due to COVD 19 impact.

Financial Allocation (Rs) :720,000.00

Financial progress (%): 99 Physical Progress (%): 64

3.11 Monitoring disease conditions of shrimp aquaculture industry in Sri Lanka

Responsible Officer(s) : P.P.M. Heenatigala

Introduction:

Infectious disease (White spot Syndrom – WSSV and Vibriosis), are the major limiting factor that directly affect for the development of shrimp culture industry in Sri Lanka.White Spot Syndrome Virus (WSSV) is the causative agent of widespread disease related with high mortality rate in cultured shrimp. It causes up to 100% mortality in commercial shrimp farmhouses, resulting in huge losses. *Vibrio*s in *Penaeus monodon* occurs due to stress, high stocking density, unstable environment and Virion particles. This study will provide necessary information such as underline causes for the disease outbreaks, pathogenic bacterial species and suitable chemotherapeutants and control measures which are required for better disease management practices in shrimp culture.

Objectives:

- To identify the WSSV resistant shrimps.
- To identify Vibrio species responsible for the luminous disease in cultured shrimp and underline courses for the disease spread.
- To monitor disease outbreaks in shrimp culture industry in Sri Lanka.

Activities carried out (Methodology)

Activity 1:

Identification of WSSV resistant shrimps

WSSV free shrimps (n = 59) from culture ponds at harvesting stage (north western province) was collected from shrimp culture ponds in north western province to screen resistant marker.

Background data was collected with the help of structured questionnaire.

PCR was conducted with commercial test kit - IQ 2000, to confirm whether the shrimps are free from WSSV infection

PCR was conducted to screen the resistant marker.

Primers NM-F: 5′ atcctctggagtggaaagca 3′

NM-R: 5′ cacctgggctcaccttact 3′

Activity 2:

Identification of bacterial species responsible for vibriosis and underline courses for luminescent vibriosis outbreak

Post Larvae, Shrimps and water samples were collected from Luminous disease infected shrimp hatcheries and ponds in north western province.

Isolation of Vibrio bacteria in TCBS media by spread plate technique

Identification of Luminous bacteria by observing bacterial colonies in the dark (figure - 1A).

Obtaining pure cultures with the help of streak plate technique.

DNA extraction and performing PCR to amplify the 16S ribosomal (16S rRNA) gene locus using universal primers (Primers: 8F: 5’ agagtttgatcctggctcag 3’ and 1492R: 5’ acggctaccttgttacgactt 3’) (Figure – 1B).

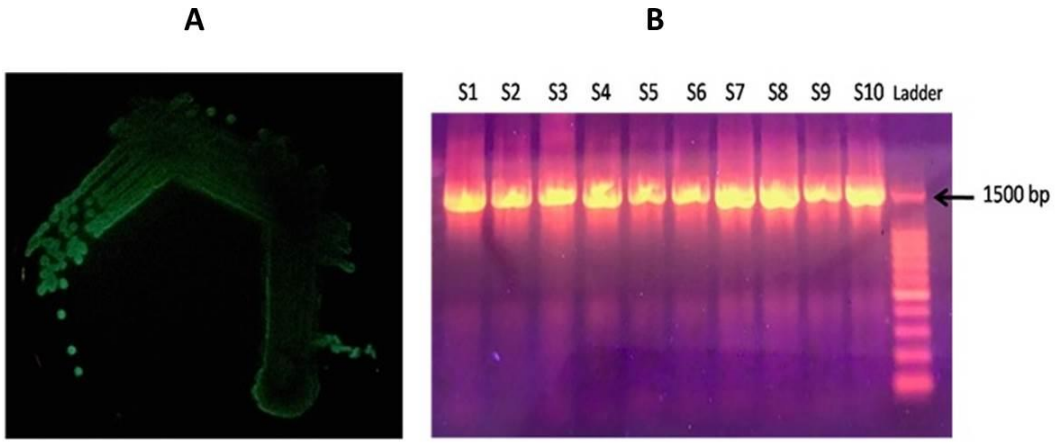


Figure 3.11-1 (A) Luminous bacteria colonies in the dark (B) PCR amplicon of 16s RNA gene sequence resolved in agarose

Sequencing (Macro gene /Korea) & species identification by NCBI BLAST.

Conduct antibiotic sensitivity tests by disc diffusion technique.

Water quality of the luminous disease infected pond and hatchery water was analyzed.

DO, pH and salinty were measured *ex situ* using portable meters

NH_3, No_3^-, No_2^-, PO_4^{-3} of the water samples were analysed by DR6000

Results

Activity 1: Identification of WSSV resistant shrimps

All samples collected (n = 59) were confirmed as WSSV negative by PCR.

All 59 samples were negative for the resistant gene marker.

Activity 2: Identification of bacterial species responsible for vibriosis and underline courses for luminescent vibriosis outbreak

Luminous disease was mainly reported in

December – February (With low temperature)

June – August (With high salinity)

All samples collectedwere positive for luminescence vibriosis.

17luminous disease incidence (*39 cultures)* - *P. Monodon* hatcheries

04 luminous disease incidence (19 cultures) - *P. Monodon* culture ponds

02 luminous disease incidence (04 cultures) - *L. Vannamei* culture ponds

62 bacteria cultures were isolated from shrimp hatcheries and farms and 37 were shown luminescence.

37 cultures showing luminescence were sequenced and 33 of them were identified as luminous disease causing bacteria. The species composition of the cultures identified was shown in figure – 2.

V.campbellii was identified as themost dominant species responsible for the luminous disease in shrimp culture practises in Sri Lanka.

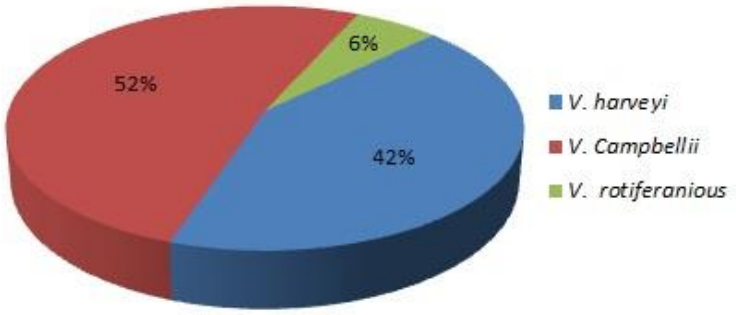


Figure 3.11-2 Species composition of the vibrio species identified responsible for the shrimp luminous disease

Table 3.11-1 Water quality parameters of the vibrio species isolated

Water quality parameter	**Bacteria species**		
	V. campbeli	***V. harveyi***	***V. rotiferianus***
NH3 (mg/l)	0.03 > 5	0.03 > 5	0.03
Nitrate (No_3^-)(mg/l)	0.3 - 1.8	0.3 -1.8	0.3
Nitrite (No_2^-)(mg/l)	0.03 - 0.09	0.02 - 0.9	0.03
PO_4^{-3} (mg/l)	0.7 - 1.4	0.82 - 1.4	1.23
Salinity (ppt)	25 - 28	25 - 28	27
pH	7.2 - 8.1	7.5 - 8.0	7.4
DO (mg/l)	10.8 - 11.08	10.5 - 12.1	11.56

Conclusions

The study has indicated that the three vibrio bacteria species, *V. campbeli*, *V. harveyi* and *V. rotiferianus* are responsible vibrio species for the luminous disease outbreaks in shrimp aquaculture industry in Sri Lanka. Moreover low temperature and high salinity enhance the disease spread in the culture system. Use of antibiotics to contr*ol luminous bacteria has beco*me ineffectivedue to the emergence of resistant strains. Thus the best method would still be prevention, with particular concentration on rigorous water management and sanitation to prevent the entry of luminous vibrios through the culture water.

Recommendations

Further research should be address to identify a suitable resistant marker against WSSV

Further research should be address to identify the gaps on rigorous water management practices and sanitation activities carried out to prevent the entry of luminous vibrios in to the hatchery and farms systems.

Outputs & outcomes

The data generated from this study will be used to develop suitable disease control measures for these impediment diseases.

Data will aid in formulating and improving regulations for better disease management practices. Facilitate to improve disease management programmes in shrimp culture industry.

Thereby minimize the losses from disease out breaks and increase the quality and quantity of production and finally income from the industry.

Ultimately safe guard the sustainability of shrimp aquaculture and shrimp production in Sri Lanka and will ensure the economical contribution from shrimp aquaculture to the national economy.

Constraints:

Covid-19 epidemic situation sampling couldn't carried out as scheduled
Lack of staff to conduct laboratory analysis
Delay in purchasing work

Financial Allocation (Rs) :305,000.00

Financial progress (%): 100 Physical Progress (%): 90

3.12 An Evaluation of Traditional Fishing Activities in Negombo Estuary, Bolgoda Lake, Madu Ganga and Jaffna lagoon and Strategies for Proper Management.

Officer/s responsible : M. Gammanpila&J. S. Jayanatha

Introduction

Small-scale coastal fisheries, an important source of income and food in many parts of the world, particularly in developing countries, account for nearly 40% of world fish catches and provide direct employment for more than 90% of the world fisher population. Many small-scale fisheries in the world are in crisis today due to over-exploitation of resources and failures to enforce the required management options. In this context, importance of participatory approaches in fishery resource management, alternative to conventional centralized resource management, especially in labour-intensive, small-scale fisheries, in many parts of the world has been increasingly acknowledged. Consequently, in fisheries management, attention has been directed towards active involvement of local communities in managing near-shore coastal resources and fishers have a wealth of knowledge and long experience, which provide valuable information for resource management of small scale fisheries in developing countries. In Sri Lanka, there are several traditional coastal fisheries including stake net fishery in Negombo estuary, kraal (Ja-kotu) fisheries in the Bolgoda lake and Madu Ganga estuary in western and southern Sri Lanka, beach seine fisheries in north-western and southern province in Sri Lanka and shrimp aquaculture practices in the north-western province of Sri Lanka are also reported. However, most of these community based fisheries management strategies have gradually began to fail due to the mechanization of world fisheries and fisher communities are challenged to preserve their traditions, fish resources and livelihoods. The management strategies initiated by the government with a centralized top-down control approach were used to manage the declining fishery resources, but they too, were largely unsuccessful in the region.

Being traditional fishing practices, fishers are expected to possess mechanisms, which utilize traditional ecological knowledge (TEK) of fishing communities for resource management. Such traditional ecological knowledge and customary management practices of community based management techniques offer great promise for improving the condition of coastal environment and management of fisheries. However, these traditional management strategies are, in most situations, not on record, and existing information does not give a complete overview of structure and functioning of fisheries.

Objectives

- To evaluate and empirically verify traditional ecological knowledge

- To provide possible recommendation for sustainable management of kraal (Ja-kotu) fisheries in the Sri Lanka

Methodology

The study was conducted to assess community based management practices adopted by Kraal fishery (Ja-kotu) in Bolgoda Lake, Madu Ganga and Jaffna lagoon in Sri Lanka.

A semi-structured questionnaire was used in interviewing Ja-kotu fishers and all the other people related to the respective fishery of Bolgoda Lake, Madu Ganga and Jaffna lagoon with a view to assess the existing fisheries management system. Nearly 90% and 88% of fishers from Madu Ganga and Bolgoda Lake areas were interviewed to collect fisheries information related to traditional fishery management practices and socio demographic information of traditional fishers. The questionnaire was focused on preliminary demographic information of their fishers including age, educational level, number of year experience, indigenous knowledge in fishing operation, factors affect to shrimp harvest including salinity, depth and distance from the sea, phases of the lunar cycle and appreciation of fishing rights for equity sharing of the resource. In addition to the questionnaire survey, group discussions and visual observations were made during fishing practices. The questionnaire also contained statements to gather information relevant to institutional robustness for averting common pool resources (CPR) dilemma in the fishery.

Results

Socio-demographic profile of Ja-kotu fishers in Madu Ganga & Bolgoda Lake indicated that majority of fishers (85%) were in more than 40 years age group and 35% fishers in Madu Ganga having over 30 years of experience in fishing. Many of them (57%) in Bolgoda lake have sufficient formal education (up to G.C.E O/L). Almost all fishers interviewed, 94% and 71% of fishers in Madu Ganga & Bolgoda Lake stated that the ownership of ja-kotu fishery was passed down from generation to generation. All Ja-kotu fishers in Bolgoda Lake were engaged in other various livelihood activities. Fishing activities and resources are voluntarily monitored by individualFishers.

Though there is no proper legislation to define user boundaries in Ja-kotu fishers in all lagoons, multi-layer institutional structure of Ja-kotu fishers in Jaffna lagoon was comparatively strong enough to own decision making process. The Ja-kotu fishery in Madu Ganga estuary faces many challenges such as lack of legalization, increase in the number of unauthorized ja-kotu, unplanned development activities, development of tourism activities, environmental pollution and rapid urbanization. Such direct and indirect issues are negatively effect on traditional user rights and livelihood of fishers.

Conclusion

The traditional community rights and institutional structure of Ja-kotu fishers in Madu Ganga & Bolgoda Lake are not strong enough to make responsible fisheries management compared with Ja-kotu fisheries in Jaffna Lagoon.

Recommendations

Mapping of existing Ja-kotu installed in Madu Ganga and Jaffna lagoon and scientifically define maximum number of Ja-kotu could be operated and suitable locations, that helps to regulate Ja-kotu fishery in both lagoons.

Low compliance of several design principles in the fishing community indicating that establishment of a coordinating body that involves of relevant stakeholders, Department of Fisheries, members from local fisheries societies, local administrators, Coast Conservation Department, Forest and Wild Life Department and the Sri Lanka Tourist Board necessary to manage the Madu Ganga wetland with special attention on tourism and fishing activities.

The community rights and institutional structure of Ja-kotu fishers in Madu Ganga & Bolgoda Lake are not strong enough to make responsible fisheries management. The uncertainty of institutions in a society can be reduced byimposing formal and informal rules. For improvement of the current situation in the Ja-kotu fishery, robust participation of the centralized management authorities is needed. As such, co-management regimes through intervention of centralized management authorities that empower local communities for using scientific and traditional ecological knowledge to make management decisions are essentially needed to be implemented for sustainability of the fishery.

Immediate action need to regulate the operation of motorized boat and engine capacity, introduce speed limits, time restriction, use of petrol engines for boat operators in Madu Ganga.

Regulate mesh size of Ja-kotu (wing and cod end) as the 1 ¼ inches for the cod-end and 5/8 inch mesh size recommended to use for the fence net (guide net) according to the present gazette in Jaffna lagoon.

Removing of stake nets (Ja-kotu) fixed at the lagoon mouth and canal areas allow better circulation of water and avoid disturbing migration pattern of fish and shrimps.

Strictly follow regulation of distance between two ja-kotu are not less than 300m.

Limitation of number of Ja-kotu and introducing of alternative livelihood activities including mariculture activities and prepare zoning plan for mariculture activities (Sea bass, Sea cucumber, Sea weed etc).

Outputs & outcomes

Identify constraints in traditional Ja-kotu fisheries in Sri Lanka.

Recommendation for an effective management of traditional Ja-kotu fisheries in Sri Lanka.

Constraints:

Covid-19 pandemic situation project activities could not carried out nearly 4 months in 2020.

Financial Allocation (Rs) :230,000.00

Financial progress (%): 99 Physical Progress (%): 70

3.13 Culture based fisheries in perennial reservoirs; related to limnological studies in selected reservoirs leading to optimum stocking of fish

Responsible Officer(s) : Amitha Adikari

Introduction:

Sri Lanka is reputed to have a very high density of reservoirs, estimated to be 171,271 ha. Fish seed stocking programs of these reservoirs are governing mainly by government body (NAQDA). Due to lacking of Information regarding the biological and limnological data of the reservoirs, presently stocking programme of NAQDA determined based on the yield of the reservoirs. Therefore still reservoir in county could not reach it optimum fish production level and huge amount of natural foods are wasted in numerous ways. Thus, this project is planning to study mainly the important physicochemical characteristics, plankton and fish production potentials which required for economical and sustainable management of reservoir.

Objectives:

- To find out the general limnology (Physical and chemical properties) in selected reservoirs in North western province.
- To find out the plankton diversity, abundance and yearly variation in selected reservoirs in North western province.
- To find out the suitable fish species, combination and stocking densities

Activities carried out (Methodology):

Study area

This study was carried out in Daduruoya reservoir and Hakwatunawa reservoir in Kurunegala district from January 2020 to December 2020. Morphometric characteristics, reservoir volume and the annul outflows of the reservoirs were collected from database of the Department of Irrigation.

Selection of sampling site

Along the longitudinal gradients by considering catchment characteristics and presence of inflow canals five sampling locations were selected as the sampling stations. Three sampling points were selected from each sampling location to obtain the maximum representation of the reservoirs.

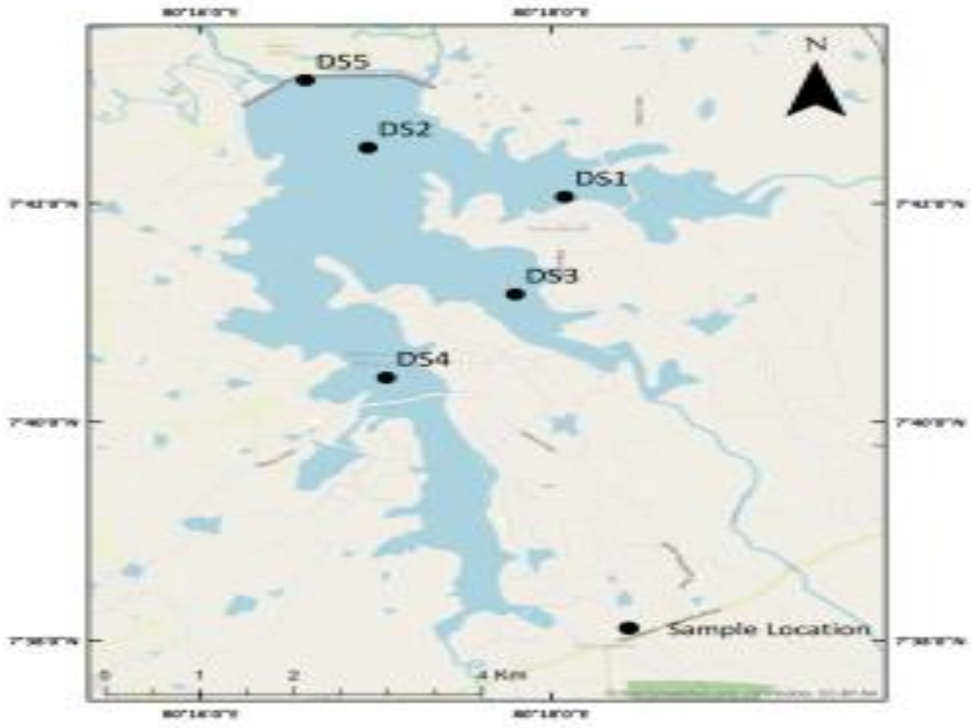


Figure 3.13-1 Sampling location of Daduruoya reservoir

Sampling procedure:

Limnological data:

Physicochemical and biological samples were collected once a month at three sampling site of each sampling location of each reservoirs. Water temperature, pH, electrical conductivity, Secchi disc death, and turbidity were measured in situ. The water samples were transported to the laboratory to analyze for Dissolved oxygen concentration, total alkalinity, dissolved phosphorus, nitrate and nitrite, using standard methods (APHA, 2013).

Biological data:

The acetone extraction method (APHA, 2013) was used to determine the Chlorophyll-a concentration. The water samples were filtered in situ through nitrocellulose membrane filters (0.45µm; 47 mm diameter) using a hand- held filter apparatus. The filter papers with filtered particles were wrapped in aluminium foil and brought to the laboratory for further analysis. All the samples were collected once a month at a 0.5 m depth in the reservoirs.

Reservoirs plankton samples were collected once a month in study sites, using a phytoplankton (mesh size 20µm) and zooplankton (60µm) nets. Plankton samples were collected preserved and analyzed following the standard methods (Hann 1990; Verschuren et al.2000) and identified using standard identification guides. Finally, the number of each individual in each species was enumerated for the calculation of relative abundance (RA). Plankton densities also were calculated using 1 ml sedgwick counting cell.

Results:

The average water temperature of the reservoirs was ranging between 28.20 ^{o}C to 30.07 ^{o}C during the study period. There was no significant change in average values of two reservoirs. The pH of reservoirs was found to be alkaline during the study period, ranging from 6.6-8 pH and it was within the acceptance range (6.5-8.5).

DO is an important indicator of ability of a water body to support aquatic life. Average DO value of the reservoirs was not significant change, ranging from 6.5 mg/l to 8.4 mg/l and it was within the acceptance rage (4mg/l).

The average value of turbidity and electrical conductivity of the reservoirs were ranging from 3.6 NTU to 7.62 NTU and 219.0µs to 338.0µs respectively. Highest turbidity value was recorded in Daduuoya reservoir as 7.62 NTU compared with Hakwatunawa reservoir.

Alkalinity of the reservoirs was ranging from 96.96 mg/l to 167.06 mg/l which was within the acceptable limits for better growth of fish and planktons (20 mg/l to 200 mg/l).

The concentration of nitrate and nitrite is indicator of level of micronutrients in water bodies and has ability to support plant growth. High concentration of nitrate favored growth of phytoplankton. The nitrite and nitrate values observed during the study period were between the ranges of 0.005 mg/l to 0.041 mg/l and 0.1 mg/l to 3.29 mg/l respectively. The values also within the acceptable range, acceptable range for nitrate is 10 to 40 mg/l and for nitrite 1 mg/l. These recorded values are favorable for growth of phytoplankton.

Phosphate content in reservoirs may be due to release of phosphate from bottom sediment and organic load of the water, this helps in growth of the phytoplankton and weed in the reservoir. Phosphorus values were range from 0.3 mg/l to 2.7 mg/l. Maximum values observed was 2.7 mg/l from Hakwatunawa reservoir during the month of February to August (except April,May) (dry season). Maximum values observed in Daduruoya reservoir during the same period was recorded as 2.4 mg/l. But these values were recorded in the month of September as 0.58 mg/l and 0.4 mg/l Hakwatunawa reservoir and Daduruoya reservoir respectively. Phosphorous values of reservoirs were above the acceptable level (0.005 mg/l to 0.05 mg/l) during the study period. Drought condition and low water level may be reason for phosphorus levels increase.

Chlorophyll a concentration of reservoirs varies from 4.1 mg/m^3 to 9.1 mg/m^3 during the study period.

Planktons were collected from the study sites during the period of study. A total of 79 phytoplankton species and 24 zooplankton species were encountered from Daruruoya reservoir. Out of 79 identified phytoplankton species, only 10 species were recorded with a relative abundance (RA) of more than 1%which include *Lyngbya* sp (12.3%), *Ulothrix* sp (10.04%), *Staurastrum* sp (4.47%), *Cosmarium* sp (3.22%), *Navicula* sp (2.84%), *Merismopedia* sp (2.13%), *Microcystis* sp (1.65%), *Pediastrum* sp (1.64%), *Ooctstis* sp (1.42%) and *Coelastrum* sp (1.05%). Out of 24 identified zooplankton species, only 9 species were recorded with a RA of more than 1%. They are *Microcyclops* sp (61.82%), *Arcella* sp (13.60%),*Chydorus* sp (6.47%), *Leptodiaptomus* sp (3.53%), *Cyclops* sp (2.79%), *Moina* (2.01%), *Paramoecium* (1.91%), *Aglaodiaptomus* sp (1.86%) and *Brachionus* sp (1.12%).

A total of 34 phytoplankton species and 39 zooplankton species were encountered from Hakwatunawa reservoir. Out of 34 identified phytoplankton species, only 13 species were recorded with a relative abundance (RA) of more than 1%which include *Lyngbya* sp (12.58%), *Cosmarium* sp (12.06%), *Lepocinclis* sp (11.22%), *Staurastrum* sp (9.26%), *Merismopedia* sp (8.73%), *Nitzschia* sp (8.21%), *Pediastrum* sp (6.92%), *Coelastrum* (3.73%), *Cyclotella* sp (3.03%), *Oocystis* sp (2.04%), *Navicula* (1.53%), *Crymbella* sp (1.29%) and *Ulothrix* sp (1.06%). Out of 39 identified zooplankton species, only 8 species were recorded with a RA of more than 1%. They are *Arcella* sp (36.10%), *Cyclops* sp (11.68%), *Leptodiaptomus* sp (11.31%), *Microcyclops* sp (10.81%), *Chydorus* sp (6.87%), *Aglaodiaptomus* sp (5.79%), Paramoecium sp (4.09%) and Brachionus sp (2.50%).

Average fish yield of the reservoirs range from 500 kg/month to 3000 kg/ month. *Tilapia nilotica*, *Catla catla*, *Macrobrachium rosenbergii*, *Lebeo rohita* and *Crichinus mirigala* were the prominent species of the catch. Recorded minor fish species are *Puntius bimaculatus,Mystus vittatus,Glossogobius giuris,and Heteropneustes fossilis.*

Monthly sample collection could not complete due to the Corona pandemic situation of country. Thus, Seasonal variation of limnological parameters, plankton density and plankton abundance could not completely examine throughout the year. Suitable fish species, combination and stocking densities could not decide under the limited available data.

Conclusions:

Complete conclusion can not be given becuase of limited availble data.

Recommendations:

This study needs to continue to next year to give recommendations on how to optimize the fish stocking programe of the perennial resevoirs.

Outputs & outcomes

Outcome- Increase fish harvest of the perennial water bodies

Output- Sustainable and economical management of perennial water bodies

Constraints:

Unable to complete the study due to the Corona pandemic situation of the country.

Financial Allocation (Rs) :780,000.00

Financial progress (%): 100 Physical Progress (%): 62

3.14 Development of ornamental fish feed and ornamental fish culture at Panapitiya Regional Research Center- NARA

Officer/s responsible : Mr. D. A. Athukorala ,M. Epasinghe Dr. H. C. Chalanika Dr. M. W. C. D. Palliyaguru (VRI)

Introduction

Ornamental fish industry has been identified as a foreign income generating option which could be further developed by the policy making and sustainable expansion. However, currently there are some immerging issues in the industry specially such as lack of quality seeds, lack of quality ornamental fish brooders and lack of cost effective quality ornamental fish feeds in the local market. Therefore, this project is mainly focused on the development of cost-effective quality ornamental fish feed and the introduction of quality ornamental fish brooders for small scale ornamental fish farmers. As there are provincial small-scale ornamental fish feed producers in Sri Lanka it is also hope to transfer the identified formulas to them and empower them with our technical know-how on the feed development.

Objectives:

objectives of the project are to develop cost-effective quality feeds for guppy and other popular ornamental fish, introduce such fish feeds to small-scale ornamental fish farmers, to minimize the importation of ornamental fish feeds, to Supply good quality ornamental fish brooders for ornamental fish farmers and to improve the quality of ornamental fish produced by small-scale fish farmers, to generate income for NARA by producing and selling ornamental fish feeds.

Activities carried out:

Proximate composition of feed ingredients were analyzed. 02trial feeds for Guppy fish were formulated and produced. 05 Platy varities, 05 Swordtail varities, 01 new Gyppy varities and Koi carp fish were produced and sold as juvenile fish, adult fish and brooder fish for small-scale fish farmers. 03 formulated ornamental fish feed types (Nursery, Grower/02 mm and Grower/5mm) were formulated, produced. After being used for the internal ponds the excess feed production was sold to the farmers. Income generated by selling fish feeds was handed over to NARA head office. Considering the feedback of farmers the feed formulas were further revised.

Remarks:

Guppy fish feed experimental trials could not be completed due to the inability of obtaining Guppy fish fry from the relevant private fish hatchery during the Kovid-19 epidemic time. However, able to obtained the required Guppy fish fry from the hatchery later and start the feed experimental trials on 2021.01.06.

Results:

Table 3.14-1 Fish fish Sales

Month	Income (Rs)	Month	Income(Rs)
Jan	23,049.00	July	48,480.00
Feb	22,225.00	Aug	13,975.00
Mar	7,660.00	Sep	8,420.00
Apr	-	Oct	10,870.00
May	-	Nov	60.00
June	6,270.00	Dec	32,640.00

Income from fish sale: Rs. 173,649.00

Table 3.14-2 Ornamental Fish Feed Sales

Month	Income(Rs)	Month	Income(Rs)
Jan	15,420.00	July	23,215.00
Feb	22,327.50	Aug	22,262.50
Mar	8,380.00	Sep	12,760.00
Apr	-	Oct	15,170.00

May June	18,610.00 33,615.00	Nov Dec	22,395.00 25,200.00

Income from fish feed sale: Rs. 219,355.00

Total Income: Rs. 393,004.00

Output

- Developed ornamental fish feed formulas
- Economical ornamental fish feeds for ornamental fish farmers
- Quality ornamental fish brooders and other ornamental fish stages for ornamental fish farmers.

Outcome

- Increased production of quality ornamental fish and locally made economical ornamental fish feeds
- Reduction of money spend to foreign ornamental fish feeds

Constrains

- Insufficient number of helpers and other staff for the centre
- Insufficient water supply in dry weather period which led to low ornamental fish production.
- Inability to obtain required fish fry for feed trials during Covid-19 period.

Financial Allocation (Rs) :140,000.00

Financial progress (%): 81 Physical Progress (%): 79

4 Institute Post-Harvest Technology

4.1 Enhancement of quality of fish handled in multiday boats, monitoring safety of shellfish and antimicrobial resistance in aquatic environment

Officer responsible : K.W.S. Ariyawansa, Pavithra Ginigaddarage, K.G.S Nirbadha, M.G.C.R Wijesinghe

Activity 1

Modifications in multiday boats

Introduction

The quality of fish landings is generally poor and fish spoilage is high particularly in the landings of multi-day boats. This is due to lack of proper fish landing and quality maintenance facilities on board the vessels and the lack of knowledge of fish handling and post-harvest practices. Most multi-day boats still aim at higher volumes and only a small portion of the landings meet the required quality standards. This has serious implications on the export trade, local supplies of fresh fish and producer prices. And also it is a need to supply wholesome fish and fishery products to local consumers as well. This quality loss accounts for a significant economic loss. From previous studies done at NARA it has been found that 30% - 40% of fish are in unacceptable quality at the most fishery harbours around Sri Lanka and the prevention of these losses is a major problem that needs to be addressed without delay.

Methodology

Preliminary steps have been taken to modify fish holds and storage in multiday fishing boats in order ensure the quality of the fish harvested in multiday fisheries across Sri Lanka. Hence, ceremonial signing of an agreement among the National Aquatic Resources Research and Development Agency (NARA), the National Engineering Research and Development Centre (NERDC) and the Department of Fisheries and Aquatic Resources (DFAR) for the designing and development of refrigeration system with storage facility for existing multiday fishing boats took place on the 15th of July 2020 at the Ministry of Fisheries and Aquatic Resources. Regular meetings were conducted, field visits to Negombo, Dickowita, Mirrissa and Kudawella fishery harbours and ice plants in Mirissa were carried out in order to gather required information and research activities related to chilled water storage, refrigeration storage and ice storage were carried out.

Results

Under refrigeration condition within 7 hrs core temperature of Skipjack tuna reached to 0^0C. Modifications are being carried out by engineers attached to NERDC. 2 boats are being modified and estimated cost for modifications are 8.5 M and 9.5M.

Figure 4.1-1. Signing of an agreement among NARA, NERDC DFAR

Activity 2

Multispectral Imaging for Automated Fish Quality Grading

Introduction

Fish quality grading plays a major role in the fisheries industry. Since fishermen tend to spend five to six days or even months in the sea, the quality of the harvest depends on the duration it takes to reach inland after harvesting. The present method of grading fish is by physical inspection. Hence, the results are human dependent and vary with experience and knowledge of the investigator. Since the reliability of the traditional method of quality assurance is questionable, the need for an accurate and reliable method is on demand. Since a multispectral imaging system allows to extract more micro-level information over traditional imaging systems, so it can be utilized in fish quality grading more effectively. Steps have been taken to assess the fish quality using multispectral imaging.

Methodology

NARA has collaboration with Sensibility (Pvt) Ltd. which is AI Technology Company based in Hatch Works (Pvt) Ltd. No. 14 Baron Jayatilleka Mawatha, Colombo 01,Sri Lanka .Multispectral images from two grades of "Skipjack Tuna" have already been taken.

Results

Digital App has been developed for identification of good quality and bad quality (2 grades) of Skipjack tuna fish. Validation of app is in progress.

Activity 3

Studying antimicrobial resistant in shrimp culture environment

Introduction

Bacterial, viral, fungal and parasitic diseases are the major causes of shrimp /ornamental farm mortality and production losses in hatcheries and culture systems. Antibiotics are commonly used to control the bacterial populations in hatcheries and farms. However these antibiotics are applied in *ad hoc* manner with consequences leading to alteration of microbial communities and the generation of drug-resistance strains of bacteria. Antibiotics could leave residues in shrimps, culture environment of shrimps which could have implications in human health. Hence it is important to be aware about the gravity of the situation in Sri Lanka and to take prompt action.

Methodology

To study the antimicrobial sensitivity in shrimp culture environment shrimps, water and sediment samples were collected from five farms (Mangalaeliya farm, Maikkulama farm, Udappuwa farm, Palanchikulama farm and Shwethapura farm) located in Puttalam district. *E.coli* was isolated from samples and sensitivity was tested against different families, ß-Lactams: Amoxicillin (AMX;30µg); Tetracycline: Tetracycline (TE;30µg) and Oxytetracycline (OTC;30µg); Macrolides: Erythromycin (E;15µg), Chloramphenicol (C;30µg). Disk-diffusion method was performed to analyze antibiotic susceptibility.

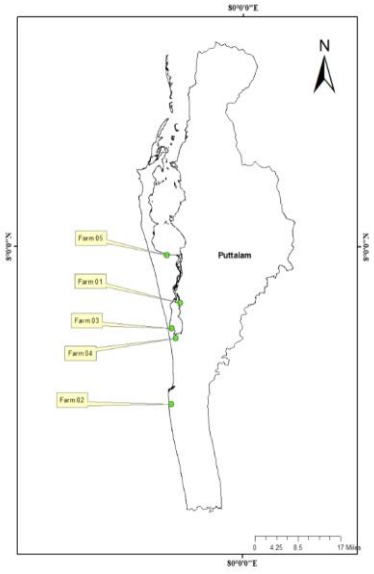
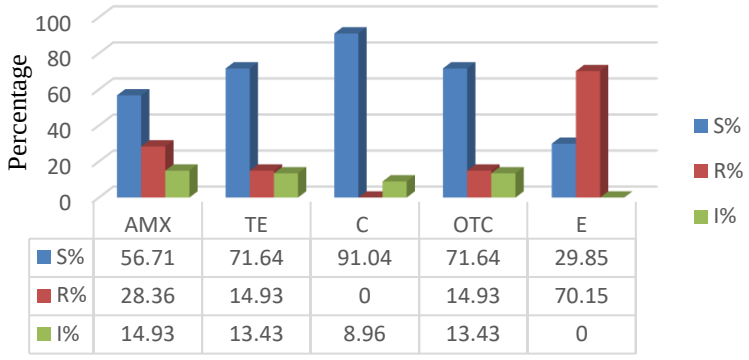


Figure 4.1-2 Picture: Sampling locations



	AMX	TE	C	OTC	E
S%	56.71	71.64	91.04	71.64	29.85
R%	28.36	14.93	0	14.93	70.15
I%	14.93	13.43	8.96	13.43	0

Figure 4.1-3 Antibiotic Resistance of *E.coli* (S- Sensitive, R- Resistant, I- Intermediate resistance)

Results

In shrimp tissues, mean values of TCC, TFCC, and *E. coli* count ranged from 0.4 to 41.9 most probable number (MPN)/g, 0.2 to 27.9 (MPN)/g, and 0 to 27.9 (MPN)/g, respectively. In pond water samples, TCC, TFCC, and *E. coli* count ranged 15-98.8 (MPN)/100ml, 5.3-73.7 (MPN)/100ml and 0-22(MPN)/100ml, respectively and in bottom sediments ranged 0.5-1.6 (MPN)/g, 0.3-0.8 (MPN)/g, and 0-0.4 (MPN)/g, respectively. A total of 67 *E. coli* were isolated and 48 isolates (71.64%) were resistant to at least one drug out of the total number. A high index of resistance to E (15µg) 70.15% was reported. In contrast, none of the *E. coli* isolates was resistant to C (30µg). Multidrug resistance to two or more

antibiotics was observed in 24 isolates. Multiple antibiotic resistance index varied within the range of 0 to 0.8 for the antibiotics used.

Conclusions

The high range of coliform count proved that unclean water of lagoons and high indices of resistance and multidrug-resistant *E.coli* strains may be a consequence of inappropriate use of antibiotics.

Activity 4

Microbiological quality of water in oyster growing areas- Negombo

Introduction

Bivalves are filter feeders able to ingest particles in suspension that may carry pathogenic microorganisms. Microorganisms like Colforms, including *Escherichia coli*, and *Faecal streptococci* are indicators of faecal pollution. The microbiological quality of bivalves becomes one of great public health significance. Negombo lagoon in Sri Lanka has identified as a potential site for bivalve cultivation and farming could be promoted as additional income for communities. If these farms are to produce bivalves for local or export market, they should be in compliance with the microbial standards. Therefore, the safety of bivalves is monitored and necessary information will be shared with stakeholders in order to uplift the industry.

Methodology

Water samples (two samples from each location) were collected from 3 locations in Negomo lagoon (Munnakarei, Talahena and Aluthkuruwa) to evaluate the microbiological quality of Negombo lagoon water for potential oyster growing.Water samples were analyzed for total bacterial counts (TBC) by the pour plate technique on plate count agar using SLS 516-1-Sec, 1:2013/ISO 4833-1:2013(E) method. Indicator organisms such as total coliforms, Faecal coliforms and *Escherichia coli* (*E. coli*) were tested using methods given in SLS Standard 1461 Part 1/ Section 3:2013 which are adopted by the laboratory with accreditation status as per ISO/IEC 17025 standard. MacConkey broth, Brilliant Green Bile Broth and Peptone water were employed to determine the most probable number (MPN) per 100 mL of total coliforms, faecal coliforms, as well as *E.coli*respectively, using a five-tube multiple-dilution technique.

Results

Density of all three types of faecal origin indicators present in water samples analysed were expressed as Most Probable Number (MPN) per 100 millilitres (100 mL) as shown in Table 1.

Table 4.1-1 Microbiological quality of water samples

Sample Number	Level of indicator organisms (MPN/100mL)			Total Bacterial Count(cfu/ml)
	Total coliforms	Faecal coliforms	*E.coli*	
01	900	130	130	7.0×10^2
02	1800+	1600	55	3.9×10^3
03	80	50	17	1.9×10^2
04	35	13	13	3.6×10^2
05	900	45	35	3.4×10^2
06	1800+	175	80	3.0×10^2

1, 2 from Munnakarei 3,4 from Talahene, 5,6 from Aluthkuruwa

According to the obtained results of water samples, it can be seen that all samples are contaminated with total coliforms, faecal coliforms and *E.coli.*Water sample1 and 2 were collected from Munakkarei area and sample number 5 and 6 from Aluthkuruwa area of Negombo lagoon and results show water is highly contaminated with total coliforms, faecal coliforms and *E.coli*. Samples from Thalahena were moderately contaminated compared to other two sites.

Conclusions

According to microbiological results these areas can be classified as class "B" based on European shell fish harvesting area classification criteria. Present study revealed that microbiological quality of water in potential sites are not up to required standards and showing the need of depuration before consumption by using very effective system comprise of UV filters, sand filters, charcoal filters, cotton filters, etc. These results also indicate the need for monitoring the quality of raw oysters, including the programs for good mollusk manipulation and management practices.

Financial Allocation (Rs) :1,330,000.00

Financial progress (%): 100 Physical Progress (%): 85

4.2 Investigation of incidences of histamine forming bacteria in chilled Yellow fin tuna (Thunnus albacares) in export fishery industry of Sri Lanka

Officer responsible : Pavithra Ginigaddarage, G.J. Ganegama Arachchi, K.W.S. Ariyawansa

Introduction

Bacterial contaminations along fish supply chain play a key role since it is very important to supply good quality safe fishery products to the consumer. Measures should be taken to reduce bacterial contaminations along the fish supply chain as fish, contaminated with certain bacteria when consumed may lead to serious illnesses such as gastrointestinal diseases and histamine intoxication. Therefore, this study aimed at investigating bacterial contaminations and isolation of histamine forming bacteria at identified control points in multiday boats landed at Negombo and Trincomalee fishery harbours.

Methodology

Sample collection points from multi-day boats (MDB) included ice (n= 30) from fish holds and chilled transport vehicles (n=30); swabs from fish holds (n=30), decks (n=30); and the skin of yellowfin tuna (n=30). Presumptive histamine forming bacteria were isolated by inoculating the samples on Nivens medium and Violet Red Bile Glucose (VRBG) agar. Plates were incubated at different temperatures (37 and 25 °C) in order to isolate bacteria that have the ability to form histamine at different temperatures. Histamine forming ability of bacteria isolates were confirmed by measuring histamine levels in broth cultures grown in trypticase soy broth (TSB) supplemented with 1.0% L-histidine at different temperatures. Histamine content was measured by using AOAC 977.13 method. PCR was done for those isolates to amplified histidine decarboxylase gene (709 bp) as described in Takashi *et al*., 2003. API 20E test kit was used to identify the isolates biochemically and further confirmation of the identities were done by amplifying and sequencing approximately 1400 bp of the 16S ribosomal DNA (rDNA) for bacteria.PCR product samples were sent to Macrogen Korea for DNA sequencing.

Results

Average Enterobacteriaceae counts of fish skin, boat deck and fish hold were found to be 2.6×10^5(range 7.5×10^2- 3.5×10^5), $9.6 \times 10^5$and 7.6×10^5 CFU/cm^2, respectively. Ice samples drawn from chilled transport vehicles had an average Enterobacteriaceae count of 6.6×10^2CFU/mL and ice samples collected from fish holds had 8.6×10^7CFU/mL. From the isolated bacterial cultures from Negombo fishery harbor majority (88.8%) were *Pseudomonas* spp. which formed low amounts (less than 30 ppm) of histamine in the broth. *Morganellamorganii*and*E.coli*were isolated from an ice sample collected from fish hold and ice sample collected from chilled transport vehicle, respectively.

Bacterial species identification of samples collected from Trincomalee fishery harbor is in progress.

Shelf life study of Yellowfin tuna to assess the histamine formation and isolate histamine forming bacteria

Apart from the sample collection from fishery harbours a shelf life study was carried out to analyse the histamine formation and isolate histamine forming bacteria in chill storage.

Methodology

Fresh yellowfin tuna samples (n=21) were obtained from a fish processing establishment in January, 2020 and samples were stored at chilled conditions (0-4 °C) the same way that the cold chain is maintained. Samples were analysed at three-day intervals for histamine content, aerobic plate count, Enterobacteriaceae count (VRBA medium) and histamine forming bacteria on Nivens medium. Plates were incubated at different temperatures (37, 25 and 7 °C).

Results

The average histamine content of the samples was 2 ppm at the initial stage and it reached 30 ppm on the 18^{th} day. Average Aerobic Plate count (APC) at 37 °C, 25 °C and 7 °C varied from 2.9×10^5 to 1.3×10^7 CFU/g, 2.0×10^5 to 8.0×10^6 CFU/g and 2.5×10^5 to 9.0×10^6 CFU/g, respectively. Average Enterobacteriaceae count at 37 °C, 25 °C and 7 °C varied from 5.0×10^1 to 2.0×10^5 CFU/g, 3.2×10^5 to 2.1×10^6 CFU/g and 3.0×10^4 to 2.5×10^6 CFU/g, respectively. Fourteen histamine forming bacterial isolates were identified which produced histamine less than 100 ppm in the 1.0 % L-histidine supplemented tripticase soy broth. Isolated bacterial species were recorded as *Aeromonas* sp. (4/14), *Pseudomonas* sp. (7/14), *Psychrobacter* sp. (1/14) and *Vibrio* sp. (2/14). Though the histamine content of the tested fish samples increased with the number of days, it did not reach toxic levels and isolated histamine forming bacteria did not produce toxic amounts of histamine in the histidine broth.

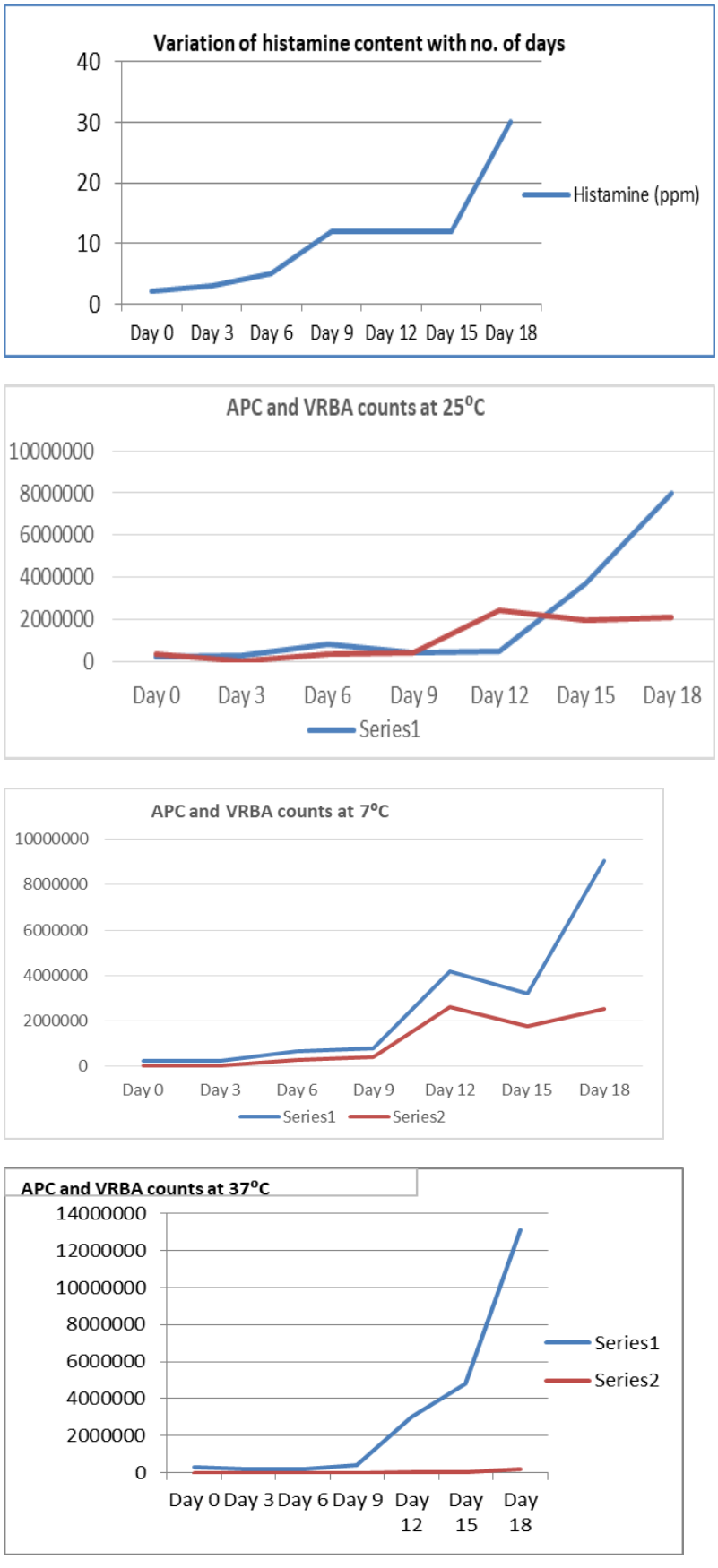


Figure 4.2-1 Variation of histamine content, bacterial count (APC and VRBA) with increasing number of days

Conclusions

Although majority of isolated bacteria were *Pseudomonas* spp. and showed a weak histamine formation in the histidine broth it is a good indication that measures should be taken to reduce the bacterial load from direct fish contacting surfaces since they are considered as spoilage bacteria as well.

Financial Allocation (Rs) :1,520,000.00

Financial progress (%): 100 Physical Progress (%): 85

4.3 Extraction and characterization of Protein and bioactive peptides using Yellow fin Tuna (Thunnusalbacares) fish waste

Officer responsible : Suseema Ariyarathna

Introduction:

Fish protein is a very valuable and expensive food component which has high demand, due to its nutritional values and health benefits therefore developing techniques to utilize low cost, underutilized and abundant fish protein sources to full fill this gap is a timely requirement. Yellow fin tuna is one of the main fish verities exported from Sri Lanka and it generates significant amount of fish wastes (fish skin, bone, head, viscera, dark meat) during processing for the export market. Fish skin, bones and viscera are discarding without proper usage creating environmental pollutions while other type of waste selling for low price. These valuable resources are considered as waste due to lack of knowledge of product development new innovation and technology. Therefore, this project was designed to find value addition technology for the fish waste especially target on the Yellow fin tuna fish wastes generate in the export related industry.

Objectives:

Development an efficient protocol to extract protein and peptide using Yellow fin tuna fish waste

Characterization of proteins /peptides extracted.
Methodology
Yellow fin tuna skin and gut were collected as raw materials (from J-Sea food- Negambo) for protein extraction trials.
Trails were conducted using two methods
Method -1

Commercially available pepsin enzyme was used to extract protein/peptide from Yellow fin Tuna fish skin.

Method -2
Yellow fin Tuna gut extract was used to extract protein instead of commercially available pepsin enzyme

Step-1: Preparation of gut extract and activation of pepsin enzyme.
Step-2 : Extraction of protein and peptide by using tuna gut extract .

Characterization was carried out for
Determination of molecular weight of proteins peptides

Method- SDS PAGE analysis (*Laemmli 1970*).

Determination of antioxidant properties of proteins/peptides

DPPH scavenging method –(AOAC *2012.04*.)

Results

Table 4.3-1 Proximate composition of yellow fin tuna skin

Moisture (%)	Protein (%)	Dry matter (%)
61.6	20.6	16.8

Table 4.3-2 Protein yield obtained from developed protocol

	Method -1	Method -2
Yield (%)	12	7

Charactrerization

Characterization part of the project was started and analyzed for SDS page and antioxidant properties. Several trials were conducted, and it was not success enough to make strong recommendation.

Conclusions

Yellowfin Tuna skin can be used to extraction of protein/peptides without discarding as a waste. Yellowfin Tuna gut extract can be used for extraction of protein/peptides from the yellowfin Tuna fish skin instead of commercillay available pepsine enzyme.

Recommendations

Characterization part of the project could not complete as scheduled due to the Covid-19 pandemic therefore it should be continued further to make strong recommendations.

Outputs & outcomes

There is a possibility to produce around 60,000 kg of fish protein powder annually using Yellow fin Tuna fish skin discarded by the processing factories and estimated market value of the product will be about 300 M LKR.

Financial Allocation (Rs) :450,000.00

Financial progress (%): 97 Physical Progress (%): 75

4.4 Development and commercialization of fish / seaweed products and extraction of bioactive compounds from seaweeds

Activity 1: Development of seaweed based vegetarian sausages and Evaluation of quality parameters

Officer responsible : P.S. Jayasinghe

Vegetarianism is the practice of abstaining from meat based foods. However, sausage which is a minced meat food item is preferred by all types of consumers due to its unique sensory properties. Thereby, this study was planned to develop a vegetarian sausage from locally available seaweed (*Gracilaria edulis*)

and oyster mushroom (*Pleurotus ostreatus*). The experiment was laid out in Completely Randomized Design in triplicates which consisted with six treatments incorporating different ratios of mushroom (MR) and seaweed (SW) (w/w); 60% MR + 20% SW, 50% MR + 30% SW, 40% MR + 40% SW, 30% MR + 50% SW, 0% MR + 80% SW and 80% MR + 0% SW. Samples were vacuum packaged and stored at -24^{o}C. Proximate composition, energy value and iodine content were evaluated. Microbiological quality and pH were analyzed in 2-weeks intervals for 150 days. Sensory evaluation was conducted with 15 trained panelists adopting Friedman test. Parametric data were analyzed using Analysis of Variance. The sensory results revealed that 50% MR + 30% SW treatment had the highest scores for all sensory attributes. It consisted of 3.93± 0.16% crude fat, 8.59± 0.87% crude fibre, 6.61 ± 0.03% crude protein, 8.21 ± 1.17% carbohydrate, 88.68± 2.02 kcal/100 g energy and 1.53± 0.12 mgL^{-1} iodine content. The yeast and mould were not detected and total plate count was 777 $CFUg^{-1}$ initially and further decreased in accordance with the Sri Lanka standards ($<1^{x}10^{4}$ $CFUg^{-1}$) for a period of 150 days at -24^{o}C storage. pH was significantly reduced ($p<0.05$) in the storage period however, it was within the acceptable limit. In conclusion, vegetarian sausage incorporated 50% MR with 30% SW (w/w) has better organoleptic and nutritional properties and can be stored at -24^{o}C in vacuum packed conditions for 150 days without any quality deterioration.

Consultancy services provided to the company Premadasas Agri Pvt (Ltd)

Compare the effect of different drying methods on the textural, physical, chemical and proximate composition of raw (*Kappaphycus alverazii)*seaweed, semi refined carrageenan and refined carrageenan.

Semi-Refined Carrageenan was obtained by the treatment of the culture strains of seaweed *Kappaphycus alverazii* of the class Rhodophyceae (red seaweeds) by removing impurities and fresh water washing and drying. According to the findings Semi refined carrageenan extracted from raw dried *Kappaphycus alverazii* moisture. ash, gel strength and pH values compatible with the FAO (1992) market standards and also Asian standards (attached-1). The required specification for appearance was tiny yellowish color for semi refined and refined carrageenan. The most similar appearance whitish yellow was observed in sun dried and solar dried semi refined carrageenan in the present experiment. The highest protein content was observed in raw seaweed dried in solar dryer than other methods. The solar dried and sun dried semi refined carrageenan showed higher gel strength and other textural properties than oven drying method. It can be concluded that most profitable and suitable drying methods for processing semi refined carrageenan is sun drying and dry in using a solar dryer.

other developed seaweed based products:

Seaweed based biscuits, seaweed based Aloe vera drinks, and seaweed based pizza. Seaweed based murruku etc.

Activity 2 : Application of Bio-Nanotechnology in Value Addition to Aquatic Resources : Preliminary study on analysis of bioactive compounds from selective marine sponges (Marine fauna) and seaweeds (Marine flora)

Officer/s responsible: K.G.S Nirbadha, M.G.C.R Wijesinghe

The Ocean, which is called the ‘mother of origin of life’, is also the source of structurally unique natural products that are mainly accumulated in living organisms. Several of these compounds show pharmacological activities and are helpful for the invention and discovery of bioactive compounds, primarily for deadly diseases like cancer, acquired immuno-deficiency syndrome (AIDS), arthritis, etc.,

while other compounds have been developed as analgesics or to treat inflammation, etc. The lifesaving drugs are mainly found abundantly in microorganisms, algae and invertebrates, while they are scarce in vertebrates. Modern technologies have opened vast areas of research for the extraction of bioactive, biomedical compounds from oceans and seas. Many bioactive compounds have been extracted from various marine animals like tunicates, sponges, soft corals, echinoderms, sea hares, nudibranchs, bryozoans, sea slugs and a few others (Harvey, 2000). Among these, the sessile invertebrates like sponges, bryozoans and tunicates are better candidate species for extraction of marine-derived secondary metabolites with drug leads (Falukner, 2002). Seaweeds are abundant in the intertidal zones and in clear tropical waters. Marine algae have received comparatively less bioassay attention. In addition, there are a number of seaweeds with economic potential. It will be of great significance if these species could be the major role players in drug development. The marine pharmacy currently holds more than 35000 marine-derived biological samples, with approximately 150 compounds to be cytotoxic against the tumour cells. Some of the prominent anticancer compounds in clinical trials include yondelis, bryostatin-1, squalamine, aplidin, dolastatin-10 (Joseph and Sujatha, 2011). In general. Natural Products have long been used as food, fragrances, pigments, insecticides, medicines, etc. Marine organisms comprising approximately half of the total biodiversity on the earth and the marine ecosystem are considered as the greatest source to discover useful therapeutics (Blunt et al., 2005). Marine biotechnology is the science in which marine organisms are used in full or partially to make or modify products, to improve plants or animals or to develop microorganisms for specific uses.

The project of preliminary study on analysis of bioactive compounds from selective marine sponges (Marine fauna) and seaweeds (Marine flora) was carried out to identify specific bioactive compounds in seaweeds and marine sponges around Sri Lanka. During the study 10 species of seaweeds (*Kappaphycus alverezii*, *Glacilaria verrucosa*, *Caulerpa racemosa*, *Padina boergesenii*, *Actinotrichia fragilis*, *Sargassum turbinatifolium*, *Anphiroa anceps*, *Avrainvillea amadelpha*, *Halimeda opuntia*, *Turbinaria ornata*) and nearly one hundred of specimens/samples of marine sponges were collected from several locations in Sri Lankan waters. Seaweed samples were identified locally using specific keys and the marine sponges samples were identified with assistance of Naturalis bio diversity centre, Leiden, Netherlands. Phytochemical profiles of seaweeds and zoochemical profile of marine sponge of *Xestospongia testudinaria* (Barrel sponge) were carried out in analytical chemistry laboratory, IPHT, NARA.

Figure 4.4-1 *Xestospongia testudinaria* (Barrel sponge) in Negombo location.

Figure 4.4-2 Seaweeds collection from Jaffna sea area

The basic chemical groups of bio active compound (Terpenoids, Flavonoids, Steroids, Glycosides, Phlobatannins, Proteins) were identified using appropriate testing methods (Salkowski test, Alkaline Regent test, Libermann test, Precipitate test, Xanthoprotein test). Ethanol was used as a solvent system for the preparation of the extract of seaweeds. The ethanolic extracts of seaweeds were undergone to the qualitatively phytochemical test by means of typical measures. Phytochemical analysis shows the

presence of alkaloids, tannins, steroids, flavonoids, and carbohydrates, whereas proteins, free amino acids and saponins were found to be absent. The results of the study may lead a foundation for the further studies on those seaweeds and sponges. The Gas Chromatography Mass Spectroscopy (GC-MS) analysis will be done for the next year due to continuity of project. Bioactive compounds interpretation of the spectrum obtaining using GC-MS analysis will be perform by comparing with data base and using phytochemical standards. The project will be continued for the year of 2021.

Financial Allocation (Rs) :1,490,000.00

Financial progress (%): 100 Physical Progress (%): 65

4.5 Development of capacities of Laboratories

Officer responsible : K.W.S. Ariyawansa, Pavithra Ginigaddarage, K.G.S Nirbadha, M.G.C.R Wijesinghe

Arrangements were made to calibrate equipment in laboratories such as incubators, water bath, ovens, autoclaves, balances, refrigerators and freezers by the Sri Lanka Standards Institute. HPLC machine uses for Histamine analysis was repaired and it is in order and fish samples from industry are being accepted for analysis. Proficiency Test samples for Histamine method validation was purchased from FAPAS UK and PT samples were analyzed in analytical chemistry laboratory. PT results were in satisfactory range. Chemicals, Standards and reference materials necessary for amino acid profile analysis and fatty acid profile analysis have been requested and is still under purchasing procedure. Arrangements have been made to service equipment (Crude fiber analyzer, dietary fiber analyzer, bomb calorimeter and oil extraction system) in analytical chemistry laboratory and renew service agreements for the preventive maintenance of equipment.

Financial Allocation (Rs) :850,000.00

Financial progress (%): 99 Physical Progress (%): 65

5 Environmental Studies Division

5.1 Investigation of causes for emergency incidents such as Oil spills, algal blooms and fish kills (Emergency Studies)

Environmental emergency incidents including sudden occurrence of fish kills, oil spills, pollution of water bodies with toxic substances, and algal blooms are very prevalent in the aquatic environments of Sri Lanka. These kinds of incidents were reported mostly with sensational media headlines and mass public protests. Their impacts can be inevitable and long lasting, and it is our utmost responsibility to prevent them from reoccurring and deal with them effectively when they occur. NARA receives information regarding emergency incidents through different source of information such as public, media, and relevant authorities. And NARA receives many requests from the public, different parties including government institutions to investigate and provide scientific reports based on the site inspection, field investigation, and laboratory analysis to reduce the negative impacts. Officers belong to other divisions of NARA such as IARAD, IPHT, MBRD and FTD also collaborate with ESD during the field investigations and reporting depending on relevancy. Total of seventeen emergency studies were carried out throughout the year, 2020.

Main objective

To identify and investigate the major causes for environmental emergencies and provide recommendation in the form of report, media release, and executive summaries to the relevant authorities.

No	Date of Investigation	Incident	Causes of the emergency situation	Output
1	11th Feb 2020	Fish kill at Beira Lake (Cinnamon Lake Hotel)	Cause of the situation was found to be reduction in DO due to increased sediment load and eutrophic condition.	Report including recommendations was provided to the relevant authority
2	March and July, 2020	Study of the distribution and impacts of the stake net (ja-kotu) fishery in Trincomalee district	To identify the present trend in stake net fishery, density and distribution of stake nets and their impacts on environment and fisheries aspects in Trincomalee district, Sri Lanka.	It is recommended to continue the study during the peak season for different species in order to identify the density and distribution thus the impacts of stake net fishery in Trincomalee district.
3	29thApr 2020	Changes of water quality in Kelani river during COVID-19 outbreak	Quality of water in Kelani river had improved due to the reduction of human activities and disposal of industrial effluents during national lockdown.	A report was submitted to relevant authorities

4	13th May 2020	Coastal water monitoring study in the western and southern coastal stretch	Quality of water in western and southern coastal stretch had improved due to the reduction of human activities and disposal of industrial effluents during national lockdown	According to the Physico-chemical analysis of coastal waters, it can be concluded that coastal water is good for fish and aquatic life
5	13th May 2020	Water quality analysis of some selected locations of Western and southern coast	Quality of water in western and southern coast had improved due to the reduction of human activities and disposal of industrial effluents during national lockdown	Coastal water is good for fish and aquatic life. However, since the present study is a one-time analysis, a better conclusion about the west and south coastal waters may be determined by long-term research
6	8thJun 2020	Large amount of garbage piled up at Mount Lavinia Beach	Cause of the situation was found to be either changes in wind direction and sea water movements or man imposed factors.	Field investigation was done and the report was submitted to relevant authority
7	7th/9thJul 2020	Fish mortality in Seeduwa	Cause of the situation was found to be oxygen depletion due to high concentration of organic pollutants and sediment load caused by heavy rainfall.	Investigation report with recommendations were provided to the relevant authorities.
8	23rdJul 2020	Fish kill in Bolgoda lake	Cause of the situation was found to be sudden adverse changes in the water due to heavy rainfall	Field investigation was done and the report with recommendations was submitted to relevant authority
9	12thAug 2020	Fish kill in Main pond of Waters Edge, Battaramulla	Fish mortality was suspected to be occurred due to the poor quality or toxic condition due to inclusion of chlorine-based disinfectants in the water	Investigation report with recommendations were provided to the relevant authorities (Management of Waters Edge).
10	31stAug 2020	Colour change of sea water – Dehiwala and Agulana	Cause of the situation was found to be the presence of single cell diatom called *Navicula sp.*, in high population density,	Field investigation and laboratory analysis were done and a report was submitted to the ministry of fisheries with English and Tamil translations.

			according to the microscopic examinations.	An Article for the "Oruwalla" newspaper was submitted, several voice records were given for the different television and radio.Recommendation was provided to implement relevant mechanisms to remove algal blooms.
11	Sep 2020	Emergency situation of oil spill happened due to MT New diamond ship burning incident	Emergency oil spill situation	Information and reports were submitted to the Marine Environment Protection Authority (MEPA) for assessing the economic cost due to environmental damage for necessary legal actions.
12	22nd Sep 2020	Fish kill at Minneriya Wewa	Cause of the situation was not identified since the investigation was done 3 weeks after the incident happened.	Report was submitted to the National Aquaculture Development Authority (NAQDA) with recommended to send the fish samples to ITI for further analysis.
13	Sep 2020	Dead turtles washed ashore in Mt Lavinia Beach		Report with possible causes for the turtle mortality was submitted to general Manager/MEPA
14	1st/2ndOct 2020	Current fisheries and socioeconomic status of stake-net (Ja-Kotu) fishery in Mannar	Gillnet fishers in the Vankalai area of Mannar claimed that their fishing activities are affected by stake-net fishing	This study was done by MBRD and recommended to remove stake nets placed in the area while introducing plausible alternative livelihood for stake-net fishers who are willing to exit from the fishery

15	22-24 Oct 2020	Research on Fyke Net and other fishing methods commonly used in Kokilai Lagoon was conducted with the participation of NARA officials and members of the Sinhapura Lagoon Management Committee.	To identify the fishing methods and fish caught in the nets.	recommend, not using trap fishing in the Kokilai lagoon ecosystem, removal of fishing nets from the Kokilai Lagoon ecosystem, especially the so-called cross nets, the use of eco-friendly methods such as caramel nets and crab traps that can be used in lagoon ecosystems, the assistance of the Navy as necessary to prevent the use of prohibited methods in the lagoon, conducting a detailed study in this regard.
16	Nov 2020	Mass whales stranding at Panadura and Wadduwa Beaches	The actual causes of the situation were not identified.	Field investigation and submission of summary reports with collaborations with MBRD to related institutions.
17	16th Dec 2020	Post-impact of the New diamond Oil spill on gills and liver of two common fish species	To identify the impact on gills and liver tissues of those fish species, a histological study should be done.	The study was done by MBRD and the collected samples were handed over to the faculty of fisheries and Marine Sciences & Technology, University of Ruhuna for histological testing. Analysis will be done after receiving the histological study results.

Photographs of garbage piled up incident in Mount Lavinia beach (8th June 2020)

Collected waste

sorted out the collected garbage

Photographs of dead fish observed during site visit of Seeduwa (9th July 2020)

Photographs taken during the site investigation of fish kill study in Minneriya wewa (22nd September 2020)

Photographs taken during the field investigation from the study of color change of sea water at Dehiwala and Agulana (31st August 2020)

Photographs taken during the field visit of fish kill study at Bolgoda lake (23rd July 2020)

Discussion with local people

Dead Prawn collected from the canal

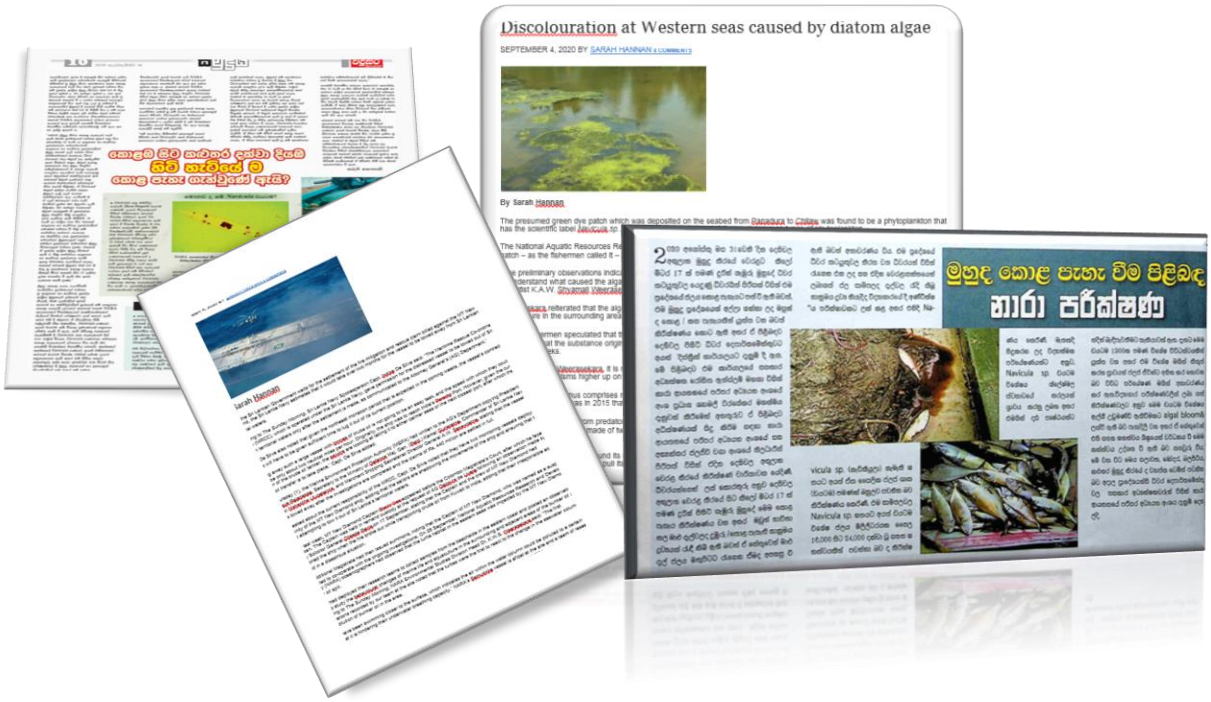
Photographs taken during the field visit of fish kill investigation at Waters edge (12th August 2020)

Dead fish found in the pond

algal bloom was found in the pond

Photographs taken during the field visit of whale stranding incident in Panadura Beach News coverage of emergency studies done by ESD

News coverage of emergency studies done by ESD



Most important emergency studies handled by the ESD in 2020 includes the fire incident in MT New Diamond Oil tanker in Sri Lankan waters, colour change in the sea water in the Dehiwala- Angulana area and piling up of lar amount of garbage in the Mount Lavinia beach. In addition to these, some situations regarding mass fish kills in different aquatic ecosystems and monitoring of water quality in some major inland and marine aquatic ecosystems were also investigated under this study. A series of studies on water quality and marine biological resources in the in both the coastal area and deep sea area of the Eastern sea of the Sri Lanka were conducted in relation to the fire and oil spill incident in MT New Diamond oil tanker and submitted a comprehensive reports to the relevant authorities and especially to the Attorney General in order to facilitate the environmental management actions as well as process of claiming the cost incurred by the Sri Lankan government in controlling the situation. Also, the colour change in the sea in the Dehiwala and Angulana area was reported to be in severe conditions and is also observed to expanding to upper sea areas as well. Team of NARA officers conducted rapid investigation over this and submitted the recommendations to the relevant authorities as well as issued the media statements relevant to the incident. In each year number of emergency situations are investigated and managed under the project 5.1 and facilitate other authorities agencies to handle the situations efficiently.

Financial Allocation (Rs) :1,650,000.00

Financial progress (%): 99 Physical Progress (%): 85

5.2 The study on impact of urban pollution on the water-sediment system of the Hamilton Canal

Officer/s responsible: M.D.S.R. Maddumage, J.K.P.C. Jayawardhane, S.R.C.N.K. Narangoda, Dr. A.A.D. Amrathunga, K.A.W.S. Weerasekara

Introduction

The Hamilton Canal is a manmade canal, located parallel to the western coast line of Sri Lanka which connects Kelani River mouth and Negombo Estuary. The bank of the canal is populated mostly by fishing community, and many fishing boats are anchored. According to the residents along the canal, earlier people have used canal for fishing and bathing but currently the environment stinks due to the polluted canal. There are sub-surface drains as well as several sub canals coming from land side connecting to the canal. Therefore, canal water is polluted from sewage, urban and industrial waste water, storm water runoff etc. Several industrial factories and organizations also located bordering the area including Kerawalapitiya Industrial Zone, Ceylon Petroleum Storage Terminal Limited (CPSTL) Muthurajawela, etc. Also, it was recorded that the water which flows through the Muthurajawela marsh ultimately reaches the Hamilton Canal due to the pattern of drainage in the area (Dassanayake, 1993). Hamilton canal has been influenced by the Kelani-Maha Oya estuaries and Negombo lagoon estuary which in turn contaminated heavily due to increasing trend in anthropogenic activities in the surrounding area (Chandrasekara et al., 2018).

A major fish kill occurred in the canal in April 2019 thus, Environmental studies division, NARA did a preliminary investigation study and revealed that it was due to heavy water pollution of the canal due to waste discharges from both point and non-point sources. During this study, we found that comprehensive data on the pollution status of the Canal and factors affecting the same are lacking. The canal has been investigated several times for the water quality but not for the planktons and the benthos which can also use to understand the impact of the anthropogenic activitieson the water-sediment

system of the canal. Therefore, the present study focused on measuring selected physicochemical parameters as well as the diversity and density of plankton and benthos in the canal system.

Project Objectives

- To determine physiochemical parameters of the water in the Hamilton canal
- To measure the diversity and abundance of algae and benthos along the canal
- Identify possible point and non-point sources of water pollution around the canal
- To study the pollution impacts on fish and aquatic life and the surrounding community

Methodology

Study Area

Two sections of the Hamilton canal from Kelani River mouth to Negombo Estuary and Negombo estuary to Maha Oya were selected for the present study (Figure 1). The section of the canal connecting the Kelani River mouth and Negombo Estuary is approximately 14.5 km long and the width is ranging between 12 to 20 m. Other section of the canal from the sea mouth of the Negombo estuary to Maha Oya is about 7.5 km long and 8 to14 m wide.

Figure 5.2-1 Map of the Hamilton Canal

Sampling

Site selection for the study was done in January and 20 locations were selected for sampling from both sections of the canal (Figure 2). Although monthly sampling is proposed in the project proposal, samplingin April, May and October, Novemberwere cancelled due to Covid -19 outbreak. Water and sediment samples were collected for physicochemical analysis and for plankton and benthos analysis.

Water samples were collected to 1L polypropylene bottles. Plankton samples were collected using 20µm plankton net and the sample were fixed using Lugol`s solution. The benthos samples are going to collect using Van Veen grab sampler and the samples were sieved using wet method (3353, 2000, 1400 and 710 µm sieves) and samples were stained using Rose Bengal solution and fixed using buffered formalin solution.

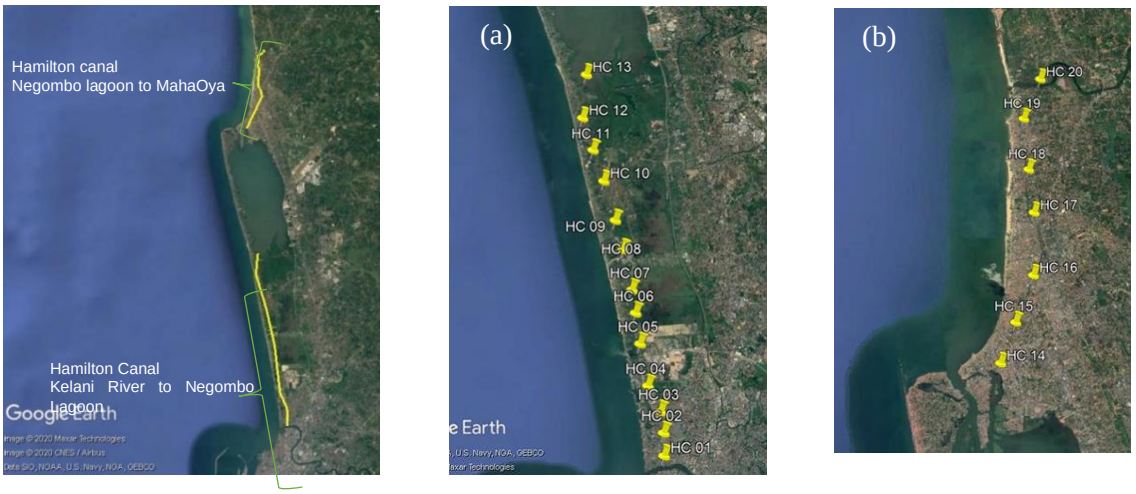


Figure 5.2-2 Sampling locations in the two sections in the Hamilton canal (a) Kelani river to Negombo lagoon section (b) Negombo lagoon to Maha Oya section.

Analysis

Selected physicochemical parameters were analyzed in water using the Standard Methods for the Examination of Water and Waste Water (23rd Edition, 2017). pH water temperature, salinity, total dissolved solids, dissolved oxygen, turbidity and Secchi disk depth were measured at each sampling site as in-situ parameters. Other chemical parameters were tested in the laboratory.

Table 5.2-1 Parameters studied and methods used

Parameter	**Principle**	**Methodology**
Water temperature	Thermometric	EUTECH CyberScan 600 pH/mV Meter
pH	Potentiometric	EUTECH CyberScan 600 pH/mV Meter
Dissolved Oxygen	Electrometric	YSI ProODO Optical Dissolved Oxygen Meter
Salinity	-	Refractometer
Electrical Conductivity	Electrometric	HANNA HI-8633N Multi-range Conductivity Meter
Turbidity	Nephelometric method	EUTECH digital turbidity meter
Total Suspended Solids (TSS)	Gravimetric	2540 D Total Suspended Solids dried at 103 –105 °C (APHA, 2012)
Ammoniacal nitrogen	Colorimetric	4500-NH3 F Phenate method (APHA, 2012)
Nitrate nitrogen	Colorimetric	4500 E Cd Reduction Method (APHA, 2012)

Nitrite nitrogen.	Colorimetric	4500 B Colorimetric method NED/Sulphanilamide (APHA, 2012)
Dissolved Phosphate (Ortho-phosphorous)	Colorimetric	4500 –P E Ascorbic acid method (APHA 2012)
Bio-chemical Oxygen Demand (BOD)	Titrimetric	5210 Winkler method (APHA ,2012) (Modified)
Chemical Oxygen Demand (COD)	Titrimetric	5220 Open Reflux Method, (APHA, 2012)

Results and Discussion

According to the results, pH of the samples varied from 5.78 to 8.19 and, the mean value was 7.08. Dissolved oxygen (DO) concentration in the canal was significantly low in most of the sampling locations. The DO varied between 0.43 - 6.34 mg/l and, the mean was 2.69 mg/l. Therefore, DO concentration in the canal is below the standard limits (3 mg/l, min) for fish and aquatic life given in CEA, 2001 ambient water quality standards. Biochemical oxygen demand is also significantly higher, ranging from 0.9 to 22.0 mg/l and, the median is 7.7 mg / l. The standard limit of BOD for fish and aquatic life is a maximum of 4 mg / l thus average BOD concentration in the Hamilton Canal is very high, indicating high organic pollution in the canal. Further, Ammonia concentration ranged between 0.01 to 3.09 mg/l with an average 0.77 mg/l and dissolved phosphate concentration varied between 0.01 - 0.45 mg/l with an average of 0.14 mg/l. Ammonia concentration also higher than the standard limit (0.94 mg/l; CEA 2001) in some sampling events. Electrical Conductivity (EC) and Total dissolved solids (TDS) of the canal was varied from 0.1 to 42.6 mS/cm and 0.09 to 21.3 ppt, respectively. High EC values (14.5 to 42.6 mS/cm) were observed in March, while relatively low EC levels were observed from June to September (0.056 to 24.1 mS/cm). The same pattern observed for TDS and salinity as well. Therefore, in the Southwest monsoon, freshwater discharge from Kelani Ganga and Maha Oya influences the electrical conductivity and salinity in the Hamilton Canal. Further, the turbidity of the canal was varied from 13.3 to 49.4 NTU during the study period. Ammonia and phosphate concentrations in the canal showed quite high concentrations. Ammonia concentration ranged between 0.01 to 3.09 mg/l with an average 0.77 mg/l and dissolved phosphate concentration varied between 0.01 - 0.45 mg/l with an average of 0.14 mg/l.

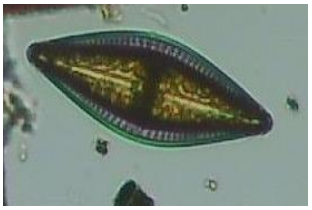
Plankton and benthic macro-invertebrate samples were observed at several selected locations along the Hamilton canal. There were nearly 45 genus of both phytoplankton and zooplankton recorded throughout the study period. Species that are found in both freshwater and marine environment were present. Most abundant phytoplankton genus was *Peridinium* sp. (Dinoflagellate) followed by *Closterium* sp., *Cyclotella* sp., *Chaetoceros* sp. and *Staurestrum* sp. while most abundant zooplanktons were Copepods. Also, considerable amount of cyanobacteria species were also present i.e. *Microsystis* sp., *Anabaena* sp., *Euglena* sp., *Lyngbya* sp., *Nostoc* sp. *Ocillatoria* sp. etc. Thus, toxin producing cyanobacteria species were present. Mean total plankton abundance of sampling locations was 2590 x 10^4 cells/m^3 and highest total plankton abundance (6024 x 10^4 cells/m^3) was recorded at HC 13 location. Lowest plankton abundance (657 x 10^4cells/m^3) was at the Kelani river estuary mouth reference point. Some identified plankton species are figured in Figure 5.2-3.

Cyclotella sp.

Euglena sp.

Closterium sp.

Dictyospharium sp.



Navicula sp.

Treubaria sp.

Figure 5.2-3 Some of the identified plankton species

There were16 different benthic macro invertebrate species recorded within the study area. Some identified families were Aricidea, Nephtyidae, Cirratulidae, Nereididae, Capitella, Sphaerodoridae, Heterospionidae together with 3 species of Arthropodes, 3 species of Gastropodes and 1 species of Bivalves. *Aricidea* sp. had the highest relative species abundance (47.56%) whereas an insect sp.(21.62%) was the second dominant species. Highest total macro invertebrate species abundance was recorded at the Kelani estuary mouth reference point followed by HC 1 (Kelani estuary end of the Hamilton canal). Several identified benthic macro invertebrate species are figured in Plate 2.

Aricidea sp.

Nephtyidae sp.

Cirratulidae sp.

Heterospionidae sp.

Amphipoda sp.

Faunus ater

Figure 5.2-4Some of the identified benthic macro invertebrate species

Figure 5.2-5 Waste water outlets and Debris in the canal

Figure 5.2-6 Sampling in Hamilton Canal

Financial Allocation (Rs) :350,000.00

Financial progress (%): 96 Physical Progress (%): 80

5.3 The study of Marine litter in coastal areas of Sri Lanka.

Officers responsible : Dr. B.R.C. Mendis, Dr. A.A.D. Amarathunga

Problem Statement/Justifications:

This study was focused on marine debris (plastic and polythene) which is recognized as a worldwide threat to marine organisms, ecological processes and economies. Marine habitats are contaminated with man-made debris and represent the major categories of marine debris by material type on a global basis. The sea around the Western, Southern and North Western province of Sri Lanka is composed of a large coastal community and is highly affected by the increasing urbanization and industrialization activities. These anthropogenic activities were increase the amounts of organic and inorganic waste input into the system and would have an impact on the overall coastal ecosystem. Therefore, dumping plastic and polythene waste into marine environment harm the aquatic biota. Thus, identification and quantification of waste input status helps in management and conservation biological and fisheries aspects.

Project Objective/s:

To identify and classify dumping of plastic and polythene waste inputs around coastal belt of Sri Lanka To give recommendations to implement conservation measures to plastic and polythene waste management.

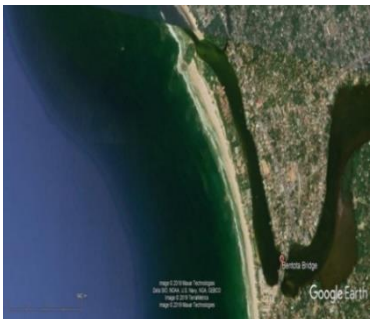
Methodology:

Marine debris was surveyed on selected sites mainly focus on river discharge outlet, estuary mouths and tourist destination sites as North - Western (Negombo and Chilaw) coastlines and Southern (Bentota, and Horathota) river basin during study period from January to December 2020. Debris cover was estimated in 100 x 10 m net using the sample collected in each site on monthly basis for macro debris (> 2.5 cm). The collected debris particles were quantified and categorized by material type.

Sampling Sites

Negombo Lagoon

Chilaw Lagoon



Benthota river

Horawala Thotupola

Results

Throughout the whole study period, marine debris was dumped waste from mainly anthropogenic activities as domestic and boats which mostly comprise of plastic and polythene waste were observed at Negombo sea mouth area. Significantly higher debris cover was found in Negombo sea mouth. According to the results obtained for the composition of debris by material types showed that the classified by use, packaging material (53%) dominated the debris, followed by consumer products (17%) and fishing items (24%) plastic bottles (6%), while food wrappers/containers contributed only 5% respectively. The study revealed that the urbanization in Negombo area was highly polluted with marine debris and their impacts on water pollution. Thus, it is recommended to make remedial measure to reduce the debris accumulation on sediment to conserve these valuable coastal habitats. It is important that the awareness of the society is re-checked and an ecology-concerned society is built via timely dissemination of knowledge and apposite policy reforms.

Conclusions

The study revealed that the urbanized Negombo area was highly polluted with marine debris and their impacts on water pollution is also high. Negombo sea mouth areas are highly polluted with marine debris compared to Chilaw and Bentota areas. Thus, it is recommended to make remedial measures to reduce the debris accumulation on sediment to conserve these valuable coastal habitats.

Recommendations

- Conduct public awareness programmes to minimize usage of plastic and polythene to reduce plastic pollution. It is important that the awareness of the society is re-checked and an ecology-concerned society is build via timely dissemination of knowledge and apposite policy reforms.
- Strong marine debris management program is needed for Sri Lanka with sound policy measures to address the debris issues.
- Implement strong rules & regulations and carry out continuous monitoring programmes to minimize/overcome marine debris pollution.
- Encourage recycling of plastics such as polyethylene, polypropylene, polystyrene without causing the environmental degradation.

Financial Allocation (Rs) :360,000.00

Financial progress (%): 97 Physical Progress (%): 85

5.4 Identification of most appropriate fresh water fish species as bio-indicators in lower and upper catchments of the Kelani river basin for Environmental pollution Assessment

The Kelani River is the principle consumable water source for 80% of the population in the Colombo district and an important ecosystem complex for the freshwater fish biota of Sri Lanka. However, it is the most polluted river in the country. It has been subjected to many pollution assessment studies over the past few years. Currently, biological indicators have been increasingly used for aquatic pollution assessment studies as they provide more precise conclusions while considering both abiotic and biotic factors.

Pollution in a water body can be judged in two ways as using abiotic tests that one of most widely used techniques and biotic tests in the water, Investigation of physiochemical properties are necessary for understanding the changes of water quality and these data provide an early warning on indication of pollution. Particular cost-effective widely used tools of quick performance for either predicting or measuring water pollution if to use of chemical testing procedures through it has no indication of the underlying damages done to the ecosystem (Lopez and Diaz, 2015). Giving conclusions depending on abiotic results only give no indication to the underlying damages happened to the ecosystem (Parmer, et al 2016). Therefore, most acceptable and recognized method is to consider both abiotic (chemical and geographical) and biotic data before any conclusions regarding water quality are drawn.

According to the existing literature fresh water fish have not been extensively used as a bio- indicator to evaluate a level of contamination in the fresh water ecosystems in Sri Lanka (Sucman, Vavrova, Gargosoava and Mahrova, 2010). Furthermore, the gravity of water pollution status of Kelani river basin is apparent due to land-based sources, agricultural runoff, domestic effluents and municipal effluents (Nandasena et al, 2019). In addition to that, heavy metal, organic waste and microbial pollution also present in some places of Kelani river basin. Furthermore, some other problem arises due to saline water intrusion from the sea making the water non-usable mostly due to sand mining of lower

catchments of river basin making severe salt wedges on several occasions (Wijesinghe, 2015). According to the Mahagamage and Manage (2014), among the major wastewater generating industries along the Kelani river basin, textile industries, rubber factories, milk food industries, beverage factories, chemical industries and fertilizer manufactories industries are contributing much more pollutants to the river (Mahagamage, et al.2014). Therefore, selection of Kelani river basin is much more important with the main task due to the presence of both polluted and non-polluted sites.

Project Objectives

This is a three-year research project consisted with two main phases and phase one consists of discovering the fish diversity, abundance and biology and some other bio indicatory characteristics of the fish species found along the lower and upper catchments of Kelani river basin. And, pollution assessment also was carried out in the same locations which were used to identify the fish species to compare with their diversity. The year 2019 mainly covered the studies on upper catchment and 2020 focused on the lower catchment. The main objectives covered were included the;

To identify the collected fish specimens up to the lowest possible taxonomic level.

To find out the fish species diversity, Relative Abundance and Species Richness for collected species to see their suitability to serve as a biological indicator.

The main objective of the phase two is to investigate the suitability of selected fish species (discovered within the year 2019 and 2020), as biological indicators by laboratory experiments to see their relationships either at the behavioral and individual level, on selected pollution pressure. Fish identification for the lower and upper catchment of Kelani river basin was completed along with the pollution assessment in the same locations selected.

Methodology

Study locations were selected based on preliminary studies and information gathered from available literature. The river basin was considered as upper and lower catchments depending on the topography of the whole basin. The lower catchment was mostly flat and extended to about 100 m and consisted of locations with different degrees of erosion and pollution. The upper catchment consisted of locations associated with a chain of mountains which started around 300 m elevation. Sampling locations within the two catchments were selected by considering the catchment characteristics, anthropological activities, industrial discharge, and availability of fish species. Twenty-six sampling locations were selected for both upper and lower catchment including 13 locations from each catchment. Certain locations were selected as reference sites which are known to have a very low pollution status according to literature. (Table 1 and Figure 1). Coordinates of each sampling location were recorded using a GPS (Hand-held Garmin eTrex 30 GPS receiver) in order to prepare the location map.

Table 1. Selected sampling locations of Kelani River basin with coordinates and site description (U denotes locations of the upper catchment; L denotes locations of the lower catchment).

No.	**Location**	**Spatial Coordinates**		**Description**
		Longitude	Latitude	
U1	Lahupana Ella	7.1048° N	80.1949° E	Forest area
U2	Kotiyakumbura	7. 7196° N	80.1656° E	Populated place – a town consisting of buildings where people live and work.
U3	Bulathkohupitiya	7.1039° N	80.3357° E	Paddy lands, tea lands and home gardens.
U4	Parussalla	7.0418° N	80.3120° E	Populated place and residential area.
U5	Wee Oya	7.0628° N	80.3361° E	Wee Oya Falls in Yatiyantota. These are two falls plunging into the same stream in the Bombepola Forest on the North of Wee Oya Estate.
U6	Panakoora	6.9118° N	80.3686° E	First tea estate in Sri lanka located between Basnagala and Dodawatte, the Noori's two main settlements. The terrain is taken over by tea on both sides of the road, but the surrounding mountains are still clothed in jungle.
U7	Alagal Oya	6.9102° N	80.3922° E	Kelani river after Kithulgala town and residential area with major tributaries added.
U8	Kithulgala	6.9844° N	80.3713° E	Kithulgala is ideally located as a stop-off between Colombo, Kandy and the tea country. Consists of jungle, tea and rubber plantations.
U9	Kalugala Bridge	6.9833° N	80.4548° E	A residential area located after the Maskeliya Bridge.
U10	Koththallena	6.8954° N	80.5048° E	Located in the hill country of Central Province. The terrain is generally mountainous, with deep valleys and consists of tea and rubber plantations.
U11	Nallathanniya	6.8244° N	80.5198° E	Water from Adam’s peak forest area with pristine quality.
U12	Goverawela B division	6.7969° N	80.5198° E	Tea estate area with small towns.
U13	Bagawanthalawa	6.7951° N	80.6840° E	River passes two small towns of Bagawanthalawa and Noorwood, tea land area.
L1	Mattakkuliya	6.9795° N	79.8756° E	Consists of an industrial area and a residential area.
L2	Thotalanga	6.9569° N	79.8783° E	Highly industrialized zone.
L3	Wellampitiya bridge	6.9372° N	79.8973° E	Oil refinery, industrialized area.
L4	Kolonnawa	6.9234° N	79.8914° E	After Diyawannawa Oya, paddy areas and home gardens and industrialized zone.

No.	Location	Spatial Coordinates		Description
		Longitude	Latitude	
L5	Ambathale bridge	6.9375° N	79.9465° E	Water intake point for purification.
L6	Biyagama	6.9392° N	79.9666° E	Industrialized zone.
L7	Kaduwela	6.9364° N	79.9853° E	Consists of an industrial area and a residential area.
L8	Nawagamuwa	6.9251° N	80.0195° E	Residential area.
L9	Panagoda	6.8686° N	80.0248° E	Paddy land area.
L10	Padukka	6.8382° N	80.0831° E	Paddy land area.
L11	Hanwalla bridge	6.9102° N	80.0834° E	Water after industrial area and several towns.
L12	Wak oya	6.5502° N	80.0554° E	Passing paddy lands and water from Labugama and Kalatuwana areas.
L13	Thummodara	6.5208° N	80.1010° N	Labugama outlet water.

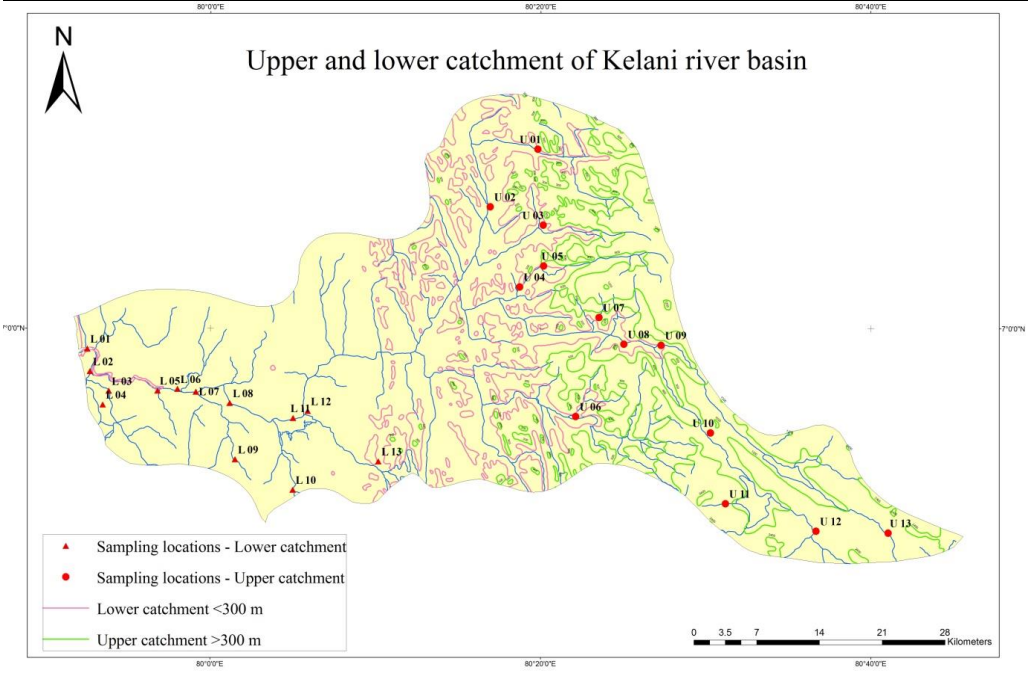


Figure 2 Selected sampling location of the upper and lower catchments of Kelani River basin

Collection of water samples and measurement of water quality parameters

Water samples were collected once in three months during a one year period from May 2019 to May 2020 from the 26 upper and lower catchment locations. The physical and chemical parameters of the collected water samples were analyzed using standard methods (APHA, 2012) with triplicates. The physical parameters, water temperature (WT) and turbidity were measured at the site itself. The HQD portable multimeter was used to measure the water temperature, and turbidity measurements were taken

using the EUTECH TN-100 portable meter. The chemical parameters such as pH, dissolved oxygen (DO), electrical conductivity (EC), total suspended solids (TSS) were measured at the sites using a HQD portable multimeter for pH and DO, and a conductivity meter for EC and TSS; biological oxygen demand (BOD), chemical oxygen demand (COD), nutrients such as nitrate – nitrogen (NO_3^- - N), nitrite – nitrogen (NO_2^- - N), ammoniacal – nitrogen (NH_3 – N), and total phosphate (T – PO_4^{3-}), total hardness and total alkalinity were measured in the laboratory using collected water samples. Five-day BOD was analyzed using Winkler method and a spectrophotometer was used to get the reading for nutrients of the samples. Closed reflux digestion method and titrimetric method were used to determine the COD, total hardness and total alkalinity respectively.

Parameter	Upper catchment		Lower catchment		Proposed ambient water quality standards for inland waters by Central Environmental Authority (1992)		Tolerance limits for the discharge of industrial waste into inland waters (SLSI 894:2008)
	Lowest value	Highest value	Lowest value	Highest value	Drinking water	Fish and aquatic life	
WT (°C)	21.53/U11	31.33/U2	26.3/L7	32.9/L6	-	-	Shall not exceed the 40^0 C
pH	6.73/U12	8.37/U9	5.33/L1	8.43/L7	6.5-8.5	6.0-8.5	6.0-8.5
DO at 25 ^{0}C (mg/l)	5.1/U2	9.2/U1	3.65/L4	8.37/L6	6 min	4 min 6 mean	4 mg/l, min at 25 ^{0}C (CEA, 2001)
Turbidity (NTU)	0.26/U12	25.23/U2	13.83/L6	85.4/L11	5	-	5 – 50 NTU (SLSI 894:2003)
EC (Electrical Conductivity) (µs/cm)	23.07/U11	452.6/U2	51.67/L7	480.53/L12	400 max	1000 max	2000 µs/cm, max (SLSI 614 part 01:1983)
TSS (Total Suspended Solids)	0.001/U12	0.048/U2	3.8/L7	45.8/L5	-	≧ 25	1000 mg/l (SLSI 894:2003)
BOD 5 day (mg/l)	1.63/U2	3.77/U12	1.2/L9	5.6/L3	2, max	4, max	30
Total Alkalinity	6.27/U11	62.8/U9	8.67L13	37.63/L1	200-400 mg/l	-	-

Total Hardness	3.41/U7	30.34/U9	15.17/L13	87.4/L4	250-600 mg/l, max	-	-
NO_2^- - N	0.0004/U9	0.0153/U2	0.0039/L2	0.0975/L7	0.01 mg/l, max	0.03 mg/l, max	3 mg/l (SLSI 894:2003)
NO_3^- - N	0.1071/U	0.5257/U2	0.1784/L1	3.5652/L5	5 mg/l, max	5 mg/l, max	50 mg/l, max (SLSI 894:2003)
NH_3^- – N	0.0105/U3	0.1794/U2	0.0313/L8	0.9772/L7	-	0.94 mg/l max	0.06 mg/l (SLSI 894:2003)
PO_4^{3-} (Dissolved Phosphate) (mg/l)	0.0026/U7	0.0783/U2	0.043/L9	0.6676/L1	0.7 mg/l, max	0.4 mg/l, max	0.7 mg/l,max (CEA, 2001)
COD	7.67/U12	25.33/U6	14.27L8	81.1/L4	15 mg/l, max	15 mg/l, max	-

\Variation of water quality results received for Kelani river basin with standard recommended values.

Statistical analysis

Multivariate Analysis of Variance (MANOVA) was conducted for the water quality parameters of the upper and lower catchments separately using SPSS version 25

statistical software. MANOVA was used to determine whether multiple levels of independent variables on their own or in combination have an effect on the dependent variable. Four multivariate measures: Wilks' lambda, Pillai's trace, Hotelling-Lawley trace, Roy's largest root were calculated to examine the variance in the data.

Results

The majority of the water quality parameters of the upper catchment of the Kelani river were within the permissible levels for drinking purposes and aquatic life. However, U2 Kotiyakumbura had high electrical conductivity values that were not suitable for drinking purposes, and U4 (Parussalla), U6 (Panakoora) and U8 (Kitulgala) had high COD levels.

Most of the locations had high DO which indicated the high saturation of dissolved oxygen in almost all the locations of the upper catchment. Nitrate pollution in upper catchment mostly due to the nitrogen fertilizers used by tea cultivation.

The Principal Component Analysis conducted for the selected locations of the upper catchment revealed nitrate concentration and chemical oxygen demand as the most suitable water quality parameters to predict the water quality of the upper catchment of the river. Within the upper catchment having good quality waters in most locations Rasbora daniconius showed high frequencies in most of the locations. These species are more frequent in undisturbed areas and could be the positive indicators of ecological integrity. Within the polluted locations Dawnkinsia singhala (Sri Lankan filamented barb) was the most abundant which presence all the polluted locations. Also, Garra ceylonensis present mostly in clean fast flowing cold waters. The highest Shanon wiener index recorded in L5 which was 2.47 and highest species richness with 14 species.The lowest value recorded in L3 which was 1.22 and comparatively low species richness as well.

Rasbora daniconius

Garra ceylonensis

Waters near Mattakkuliya (L1), Kolonnawa (L4) and Kaduwela (L7) were the most polluted with regard to many parameters, and all three locations had high levels of phosphates.The present study, the phosphate concentration of the lower catchment ranged from 0.04 – 0.67 mg/l, which is more or less similar to the values recorded since 2017. The total suspended solids (TSS) were also high in L1 and L4 and the waters of L7 had high levels of nitrogen in the form of nitrites and ammonia.With the exception of L7 Kaduwela and L8 Nawagamuwa, COD concentrations were significantly high in all the selected locations of the lower catchment and ranged from 15.63 mg/l (L6) to 81.10 mg/l (L4).

Within the polluted locations Dawnkinsia singhala (Sri Lankan filament barb), which is previously identified as Puntius filementosus (Pethiya) was the most abundant which presence all the polluted locations. It could be consider as a negative indicator that positively associated with disturbances.

Puntius filamentosus

Some photographs of field works

Financial Allocation (Rs) :290,000.00

Financial progress (%): 99 Physical Progress (%): 80

5.5 Assessment of Water Pollution Status of Selected Fishery Harbours in the Southern Province of Sri Lanka

Introduction

A fishery harbour is a complex center of activities which are potential waste generators and thus considered as coastal pollution hotspots. Discharge of burned oil and bilge water from fishing vessels to harbor waters, production of load of organic wastes which derived from fish degutting, market floor runoff, cleaning and garbage dumping are main causes for the water pollution in fishery harbours (Holmgren, 1994).In addition, other pollution sources in a fishery harbour includes improper dumping of fish offal and other garbage into harbour waters, dumping of untreated sewage from toilets and defecation inside the harbour premises. The use of contaminated water for fish may cause for the post-harvest losses due to spoilage from bacteria and chemical reactions. To improve the water safety and quality of a fishery harbour, its pollution level should be thoroughly assessed.

Objectives

- Determine the current status of water quality in three selected fishery harbours namely Puranawella, Mirissa, and Kudawella
- Collect information on the present status of anthropogenic activities which pollute the harbour.
- Provide recommendations to prevent harbour water pollution and minimize post-harvest loses due to spoilage.

Materials and Method

The study was carried out in seven sampling points located within the each harbour from February to December 2020 using random sampling techniques. Physical, chemical and biological parameters of water quality were measured. In-situ parameters such as water temperature, pH, salinity, electrical conductivity, dissolved oxygen, turbidity were measured. Ammonia, Ortho-phosphorus, Nitrate and Nitrite concentrations, Total suspended solids, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), oil & grease and chlorophyll-a were the tests carried out in the laboratory. Water samples were carried out to identify phytoplankton and zooplankton species. All the tests were performed according to the standard methods for Water and Waste Water Analysis given by American Public Health Association (APHA, 2012).

Sampling locations Mirissa fishery harbour

Sampling locations Puranawella fishery

Sampling locations Kudawella fishery

Sample collection

Results and Discussion

Results revealed that the pH and Dissolved oxygen were within the standards limits of the water quality for harbour waters (Table 1).

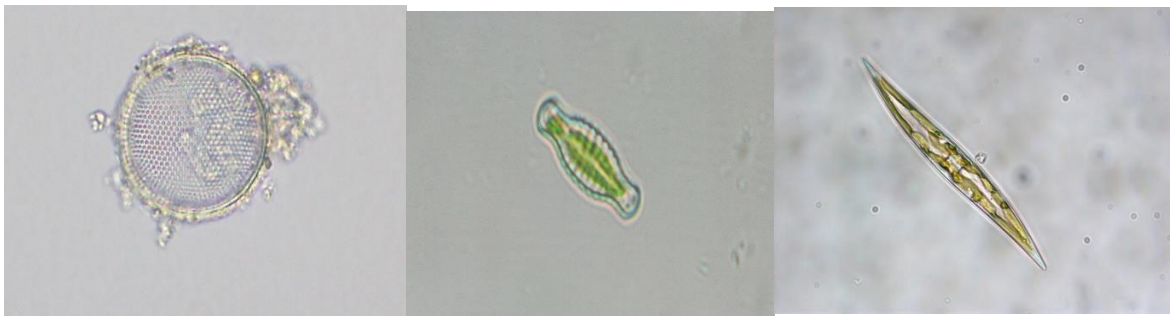
Table: Summary of the Physical parameters of the study area

Parameter	Kudawella	Mirissa	Puranawella
Temperature (C^0)	27.3 ± 0.13	27.1 ± 0.09	28.8 ± 0.07
pH	8.0 ± 0.03	8.2 ± 0.19	7.8 ± 0.37
EC (mS cm^{-1})	48.0 ± 1.9	49.8 ± 1.12	55.3 ± 0.26
TDS (ppm)	29.2 ±1.09	24.9 ± 0.51	27.5 ± 0.14
Turbidity (NTU)	8.9 ± 7.85	2.9 ± 1.28	7.6 ± 3.3

Summary of the Chemical Parameters of the study area

Parameter	Puranawella	Mirissa
DO (mg/L)	10.4 ± 5.2	21.3 ± 11.8
BOD (mg/L)	5.37 ± 1.10	8 ± 4.5
Phosphate-P (ppm)	0.0218 ± 0.03	0.0449 ± 0.02
Nitrate-N (ppm)	0.0157 ± 0.004	0.0502 ± 0.01
Nitrite-N (ppm)	0.007 ± 0.002	0.0084 ± 0.0005
Ammonium-N (ppm)	0.0216 ± 0.018	0.0891 ± 0.01
Oil and Grease (mg/L)	225.5 ± 86.46	244.4 ± 84.691
Chl-a (mg/m^3)	2.5908 ± 0.74	3.8 ± 3.19

The results of the study revealed that the average BOD (5.37 ± 1.10), (8 ± 4.5) mg/L and oil & grease (225.5 ± 86.46), (244.4 ± 84.691) mg/L, in Puranawella and Mirissa showing high level of water pollution of the harbours as indicated in Table 2.Therefore it was revealed that, average concentrations of BOD in all the fishery harbours were above the recommended value (<4 mg/L) of environmental quality standards by Central Environmental Authority of Sri Lanka and primary water quality criteria for class SW-IV harbour (3mg/L) (Niroshana*et al*., 2013). Thus, it reflects that the organic pollution is pronounced within three harbours and it is indicating the presence of load of organic matter. Disposal of solid wastes including fish offal, food waste and inadequate waste receiving facilities may be the most possible reason to record these high BOD values. Oil and grease content all harbours exceeded 10 mgl-1, which is the value recommended for the harbours according to the primary water quality criteria for class SW-IV harbour waters. Emission of engine oil from fishing vessels and accidental oil spillage during the refueling activities may be the possible reasons for observing high oil & grease content in the study sites. *Pleurosigma*sp, *Protoperidium* sp., *Fragilaria sp., Thalassiosira* sp., *Actinoptychus, Coscinodiscus sp., Nevicula sp.etc*were identified as most abundant phytoplankton species within the three sites. Sociological survey results indicated that they have no specific method to remove polysac bags,bilge water and discard fish offal.



Cocinodiscus sp.Fragilaria sp.Pleurosigmasp

The study revealed that, the water quality has been degraded and all three harbours are subjected to severe oil pollution and organic pollution. Hence, this study suggests recommendations as; develop waste receiving facility for all multiday boats in each harbour; implement tight regulations in disposal of solid wastes, waste oil and biological waste including fish offal; introduce proper monitoring programmes to identify harbour pollution and aware the fisheries community on the negative impacts of harbour pollution and negative impacts due to contaminated food fish. Due to COVID-19 pandemic yearlong study could not be completed. So, study have to be continued for another one year to complete all the samplings with microbial analysis.

Project highlights

Repairing boat

Abundant boats

Oil layer in harbour water

Turbid harbour water

Financial Allocation (Rs) :400,000.00

Financial progress (%): 86 Physical Progress (%): 90

6 National Institute of Oceanographic and Marine Sciences Division

6.1 Tuna Fishing Ground Advisory and Fisheries Information Service

Officers :S.S.Gunasekara ,Udeshika Wimalasiri
Division : National Institute of Oceanography and Marine Sciences, NARA
Duration : 2020 (January to December)
LocationSource of funds: NARA

Introduction

The fishery has a long tradition in Sri Lanka and contributed 1.1 % of GDP in 2019 (CBSL., 2019). The marine fishery is the dominant sector of the fisheries in Sri Lanka, which has contributed 82.1% to the country's total fish production (Ministry of Fisheries., 2020). The coastal fisheries sector contributes 58.4% of total marine fish production, and offshore fishery sector contributes remaining 41.6%. About 90% of fishing vessels (44091 vessels) are operated within coastal waters while the rest (4885 vessels) are operated in EEZ and high seas. Offshore tuna fishery has a significant contribution to the economy as tuna contributes 49.5% of total fish exports of 299 million US$ in 2019 (Ministry of Fisheries., 2020).

Offshore fishery of Sri Lanka operated with longline, gillnet and ring net or combination of them. Longline fishery mainly target large pelagic species such as yellowfin tuna, bigeye tuna.

Fishing ground forecasting system for Sri Lanka was developed in 2007 and implemented in 2008. Experimental level forecast was released once a week and disseminated to selected fishing vessels and validated the forecast with fish catch received by forecasted fishing grounds. After successful validation effort, with encouraging results, forecast dissemination expanded to all major fishing harbors. Since 2015 the fishing ground forecast was disseminated two times a week. During 2016, fuzzy logic base forecasting model was developed and accuracy assessment show 67% accuracy of improved forecast.

Objectives

To enhance the economic efficiency of offshore/high seas fishery by providing information on potential fishing ground advisory to multi-day fishing vessels

Output

- Fish forecasting recommenced on 2020/01/01
- Weekly three forecast maps were updated.
- Increase dissemination of forecast 200 to 350.
- Fisheries data analysis

Outcome

Enhanced high seas fishery of Sri Lanka, with precision fishing, and high fish catch rates.

Methodology

Project area

Project area consists of the Indian Ocean where large pelagic fishing operations conducted by Sri Lankan fishermen from all coastal districts.

Data collection

Sea surface temperature

Sea surface temperature data obtained from GPM Microwave Imager (GMI). The Global Precipitation Measurement (GPM) satellite has a microwave radiometer onboard called GMI (GPM Microwave Imager). GMI data are produced by Remote Sensing Systems and sponsored by NASA Earth Science funding. Data are available at www.remss.com.

Sea Surface height

GLOBAL OCEAN GRIDDED L4 SEA SURFACE HEIGHTS AND DERIVED VARIABLES NRT a product from CMEMS is used obtain Sea Surface Height. This product is processed by the SL-TAC multimission altimeter data processing system. It serves in near-real time the main operational oceanography and climate forecasting centers in Europe and worldwide. It processes data from all altimeter missions: Jason-3, Sentinel-3A, HY-2A, Saral/AltiKa, Cryosat-2, Jason-2, Jason-1, T/P, ENVISAT, GFO, ERS1/2.

Sea surface chlorophyll

The Sea surface chlorophyll data acquire from HERMES web interface (http://hermes.acri.fr/) of Globcolour project. GlobColour data (http://globcolour.info) used in this study has been developed, validated, and distributed by ACRI-ST, France.

Global Ocean Model data

The Copernicus Marine Services (CMEMS) provides regular information on the physical state and dynamics of the global ocean. Global ocean ¼° physics analysis and forecast product is updated daily and provide temperature of 43 vertical levels. Global physical analysis and coupled forecasting product includes daily mean files of temperature, salinity, currents, sea level, mixed layer depth and sea ice parameters. It is freely available for registered users at Copernicus Marine Service website (http://marine.copernicus.eu). This product is generated from the UK Met Office Global Seasonal coupled forecast system (GloSea5) which is used to provide 7 days of 3D global ocean forecasts, at ¼ degree, updated daily (MacLachlan et al. 2014). This forecast product is assimilated observations from satellite SST data (Advanced Very High Resolution Radiometer (AVHRR)data and MetOp satellites supplied by the Global High-Resolution Sea Surface Temperature (GHRSST) project), Insitu SSTs (from moored buoys, drifting buoys and ships), Sea level anomaly observations (from Jason2 and CryoSat2) and Sub-surface temperature and salinity profiles (from Argo profiling floats, underwater gliders, moored buoys, marine mammals, and manual profiling methods).The Global Ocean output files are displayed with ¼°horizontal resolution with geographic projection. It also provides 43 vertical levels ranging from 0 to 5500 meters.

Data analysis and forecasting

Fishing ground forecasting

Satellite data, model data were download and processed three times a week. Multi criteria model developed under previous project is used to predict potential fishing areas for tuna. This output is coupled with depth prediction model and produce final map for dissemination.

Fishing depth prediction

The operational metrcator global ocean analysis and forecast system os providing high resolution 10 days of global ocean forecast which are updated daily. This product includes daily mean temperature, salinity, currents, sea level and mixed layer parameters from the top to the bottom, it also includes hourly mean surface fields for sea level height, temperature and currents.

Activities

- Fishery data collection: VMS data fisheries data
- CMEMS ocean model data download and analysis
- Model development
- Generating fishing ground forecast maps
- Validation of results
- Disseminate information by telephone, fax, radio, email and web to the users
- Awareness programs for fishermen, vessel owners and other stakeholders

Results

Tuna fishing ground forecast

96 potential fishing ground forecast maps were produced and disseminated via email, telephone and other web based sources during 2020.

Only 66% of forecast production and dissemination target was achieved during 2020. During March, April and May forecast map did not produce up to predicted level, due to COVID lockdown in the country. In other months there were several limiting factors such as technical failures of computers, unavailability of external data, internet connection and unavailability of human resources.

Operational fishing ground forecasting depends on availability of near real time satellite data and global physical forecast products. There were several events due to service providers maintenance and breakdowns caused to interrupt project activities. Those events can not be avoided as NARA have not capacity to receive direct satellite data and processing at NARA. Also , NARA has limited capacity to develop NARA own physical ocean models for ocean state forecasting.

Fisheries awareness interviews have been conducted on Dikowita, Negombo, Mirissa, Dikwella, Nilwella and Gandara fisheries harbors.

E-mail users community has been improved from 200 to 350 uses in the year 2020. This user community include fishing boat owners, skippers and fisheries officers.

The fisheries information was disseminated via NARA web portal, NARA official social media page and skipper’s social media page.

Recommendation

Incorporate ocean physics models and in-situ information to improve prediction. As our current fishing ground advisory based on near-real time data, it would be highly advantageous, if we could provide fishing ground advisory based on forecasted ocean conditions few days ahead. Thus, fishermen will be able to plan their cruise based on advisory and ultimately receive more economic benefits than just roaming for fishes here and there in the ocean.

Increase awareness of skippers and owners of multiday fishing boats about potential fishing ground forecast of NARA will be key factor to success of project. Therefore, awareness programs should conduct frequently.

VMS and logbook dataset need to process and analyses for accuracy assessment of fisheries logbook data and improvement of Tuna fishing ground forecasting system of NARA.

Conclusions

Fishing ground forecasting and fisheries information service project has been successfully conducted its activities with few limitations.

Financial Allocation (Rs) :110,000.00

Financial progress (%): 92 Physical Progress (%): 90

6.2 Numerical Model in Assessing the Impact of Offshore Dredging on the Coastal environment Along Wadduwa-Negombo

Officers	:R.M.R.M.Jayathilake
Duration	: 2020 (January to December)
Budget(FY 2020)	: LKR 0.5 Mn
Location	:The South-west Coast of Sri Lanka
Source of funds	: NARA

Introduction

Sand mining is the removal of sand from their natural configuration. Sand is used for all kinds of projects like land reclamations, the construction of artificial islands and coastline stabilization. These projects have economic and social benefits, but sand mining can also have environmental problems. Environmental problems occur when the rate of extraction of sand, gravel and other materials exceeds the rate at which natural processes generate these materials. The morphologies of the mining areas have demonstrated the impact of mining with the prowess to destroy the cycle of ecosystems. Numerous publications have been written with respect to these effects, and the next step is what to do to minimize, prevent or correct these environmental effects, the so called mitigating measures (Pielou, 1966).

The Colombo International Financial City (CIFC) development built as an extension of the Central Business District of Sri Lanka's vibrant commercial capital, Colombo, spanning 269 hectares of reclaimed land from the sea. The sand extraction site for CIFC Project extended from Hendala to Basiyawatta. The dredging site 1 (see Figure 1) is located 2.1 km away from the Basiyawatta and 2.8 km away from the Dambagamawatta, while site 2 is 5.5 km away from the Thalahena and 7.5 km from Pamunugama. The area is mainly consisted with a sandy seabed and hard bottom habitats.

The effects of intense mega sand extraction on coastal environment are only poorly known. The extraction has changed significantly the shape, volume and height of the sandbank. However, this

altered morphology could also influence the current and wave patterns in the coastal waters, with possible implications on erosion of the coasts. For coastal defense re-alignment, modification, planning and implementation of current and future coastal defensesrequire the information include choices about mining locations and quantities which reduces the environmental impacts. Such a strategy requires knowledge on the impact of very large-scale offshore sand mining along the Sri Lankan coast.

Mining history of the site and its environs

Licenses issued for sand extraction have included the following organizations:
South Asian Gateway Terminal Project in 1999
Bogala Graphite Lanka (Pvt) Limited from 1999 to 2001
Road Development Authority from 2001 to 2003
Vanoord- Sierra Networks (Pvt) Limited from 2006 to 2008
Asia Dredging Limited from 2004 to 2005
Sri Lanka Land Reclamation and Development Authority (SLLRDA) from 2005 to 2008 and2011-2012.
South Asian Gateway Terminal Project in 1999
Sri Lanka Ports Authority, 2011-2013Based on the report Geotechni

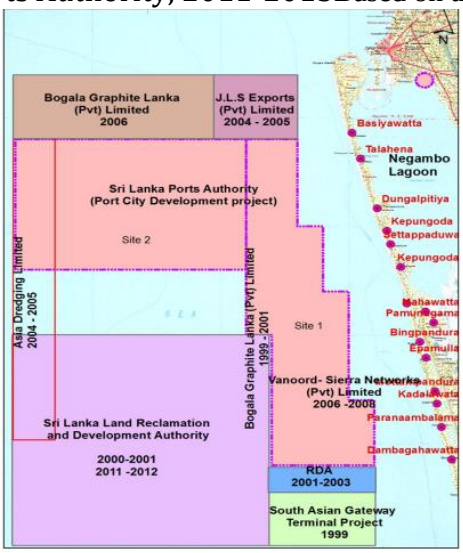


Figure 6.6.2-1.1 : Mining History of the area

The Geological Survey and Mines Bureau (GSMB)has estimates the total potential sand deposit at the proposed site 1 at about 44 million cubic meters while it is 68 million cubic meters at the proposed dredging site 2.

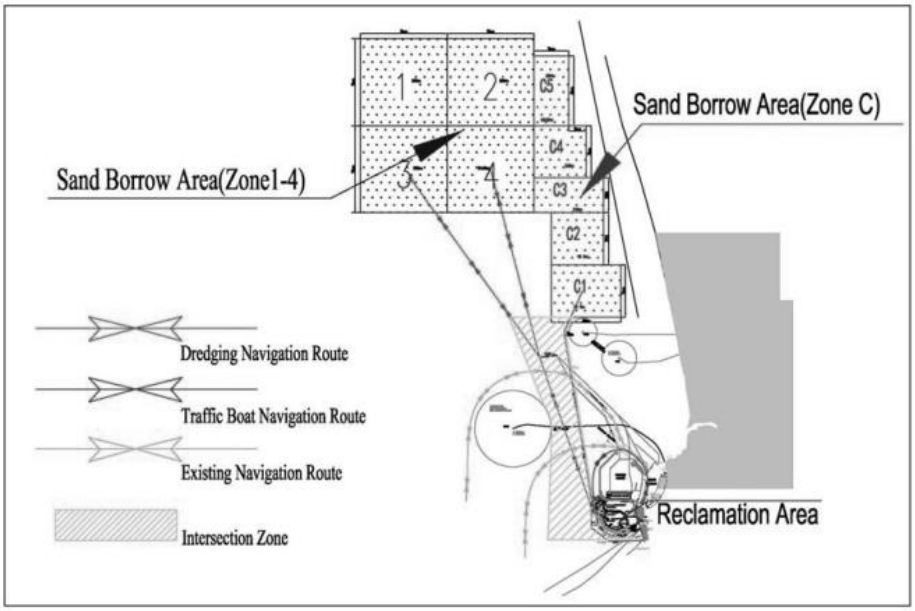


Figure 6.6.2-2.2 : Schematic partition diagram of dredging operation for Site 1 & 2 (Source: Geotechnical investigation and geophysical survey of SEIA Report, November 2015)

The required sand quantity for the purpose of reclamation on port city project (Supplementary Environmental Impact Assessment Report, 2015) is about 60-65 million cubic meters. However, according to the relevant conditions of development permit of Colombo Port City Development Project, the sand extraction carried out in the sand extraction Site 2 allocated to Sri Lanka Ports Authority (fig 1) and sand extraction did not allowed in sand extraction Site 1 allocated to Sri Lanka Ports Authority as recommended by the Technical Evaluation Committee (TEC).

Therefore, the additional amount of sand for reclamation works for the Colombo Port City Development Projectwas taken from the borrow site (Site 3) allocated to the SLLRDC as proposed and identified by the Project Proponent.

Approvals to dredge, a quantum of 70 million m3 of sand from the same sand borrow area is requested from the Central Environmental Authority (CEA) by SLLRDC to be used on the following basis:

Approximately 30-40 million m^3 of sand to be extracted over a maximum 3 year period to meet a portion of the total requirement of 65 million m^3 needed to complete the Colombo Port City project.

Approximately 30 million m^3 to be extracted over a period of 15 years for the purpose of meeting the increasing demand for sand for the construction industry and to mitigate the adverse environmental impacts of river sand mining.

The results of the Geophysical Investigations carried out in 2016 shows that a total of 187 million m3 of sand is available in the proposed Site 3. After keeping a safety margin of 0.5m thick sediment, a total of 144 million m3 is available for extraction. The average thickness of the sand deposit varies from 1.95m to 2.45m. According to the borehole investigations the minimum and maximum thickness of sand deposit within the site is 0.4m and 4.9m respectively.

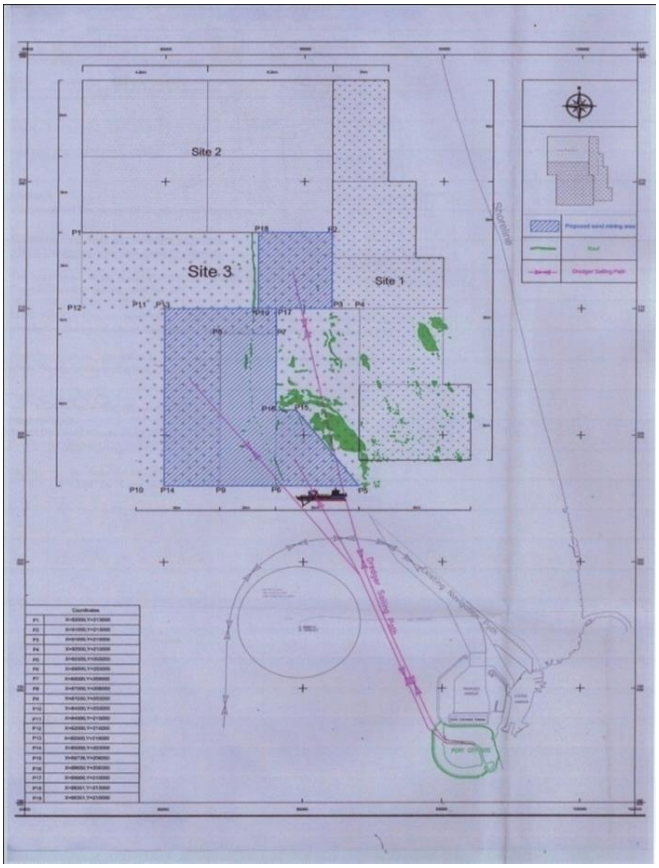
The detail of the four sub areas are given in the table6.2.1.

Table 6.2.1 : Available sand quantities in four sub areas of site 3

Sub Area	Area after calibration (Km2)	Average Water Depth(m)	Average thickness after reserving 0.5m (m)	Estimated Reserve Volume after reserving 0.5m (million m3)
S1	18.77	28.2	1.80	33.1
S2	8.56	21.1	1.82	15.0
S3	30.57	29.3	1.81	53.4
S4	25.10	21.9	195	42.6
Total Volume (m3)				144.2

The Site 3 is divided in to four sub areas S1,S2,S3 and S4 as shown in the figure 6.2.2. The schematic diagram of this additional dredging operation for CIFC is shown in the figure 6.2.2 and the required sand for the Colombo Port City Development Projectwere dredged in the sand extraction sub-areas of S2 and S3.

The sub-area of S1 is proposed for required sand extraction of proposed Beach Front project.



Guidelines for sand extraction (SEIA 2016):

Dredging to occur 3km beyond the shoreline and at water depths of 8m or more. (no impact on coastal erosion and the minimize impacts on fishing routes and fishing activities).
Dredging depth to be limited to 3m from the surface of sediment provided 0.5 m of sediment is preserved after extraction
As much as possible, dredging has to be avoided in areas having fish spawning and unique habitat.
Allow fishermen to engage in fishing within the allocated dredging sites by giving proper notice in advance and after dredging work is done to re-commence fishing.
Implement an income support and benefits program to fishermen.

Objectives

The main objective of this study is to derive a modeling approach to determine the impact of dredging on waves, currents, sand transport rates and morphologyon adjacent coastal environment of Negombo-Wadduwa coastline, Sri Lanka. To this end, we will establish a process-based coastal area morpho-dynamic model for the western region of Sri Lanka and calibrate the model against the measured data.

Methodology

Model description and settings

Numerical simulations were carried out by means of the process based model Delft3D to obtain state-of-the-art estimates of the annual long-shore sediment transport rates. Delft3D combines a short-wave driver (SWAN), a 2DH flow module, a sediment transport model (L. Van Rijn & Boer, 2006), and a bed level update scheme that solves the 2D sediment continuity equation. In particular, the hydrodynamic and sediment transport module Delft3D-FLOW, and the wave module Delft3DWAVE were used (G. R. Lesser, 2009). The Delft3D-FLOW and Delft-3D-WAVE exchange information by means of online coupling.

Delft3D-WAVE simulates the evolution of random, short crested wind-generated waves in diverse water bodies. This module is based on SWAN (Simulating Waves Near shore), a third-generation wave model that uses action density (σ, θ) (equal to energy density divided be the relative frequency) to describe development of the wave spectrum. Delft3D-WAVE simulates the evolution of random, short crested wind-generated waves in diverse water bodies.

$$N(\sigma, \theta) = E(\sigma, \theta)/\sigma \quad (1)$$

Delft3D-Wave solves the action balance equation in stationary mode, with finite difference schemes in the space and spectral dimensions. Geographic space is discretized with a rectangular grid with constant resolutions $\Delta x, \Delta y$ while the spectrum in the model is discretized with constant directional and relative frequency resolutions $\Delta\theta$ and $\Delta\sigma/\sigma$ respectively (WL Delft Hydraulics, 2000). In the present study, these two modules are coupled in an online mode to have a dynamic interaction for which the effect of flow on waves via set-up, current refraction and enhanced bottom friction; and the effect of waves on current via forcing, enhanced turbulence and enhanced bed shear stress (Hydraulics, 1999) are taken into account.

Delft3D-FLOW simulates flow and transport phenomena resulting from tidal and meteorological forcing by solving the unsteady shallow water equations in two (depth averaged) dimensions. The system of equations, derived from the three-dimensional Navier-Stokes equations for incompressible free surface flow, consists of the horizontal equations of motion, the continuity equation and the transport equations for conservative constituents. Numerically, the partial differential equations are solved by finite differences once they are discretized in space with the use of curvilinear or rectangular grid cells (Hydraulics, 1999). The complete set of these models is known as DELFT3D-MOR.

Steps that are taken for Delft 3D Wave/Flow is shown in figure 6.2.2.

Establish a process-based coastal area morpho-dynamic model for the study area.

Calibrate and validate the model using measured data (sediment concentration, flow velocity and cross-shore profile evaluations).

Model coastal system response to waves, currents, sand transport rates and morphology derived under different sand extraction trench geometries using the model in 1 and 2.

Investigate near-shore wave climate changes, current, sediment transport and morphology on the coastal environment for different dredging scenarios.

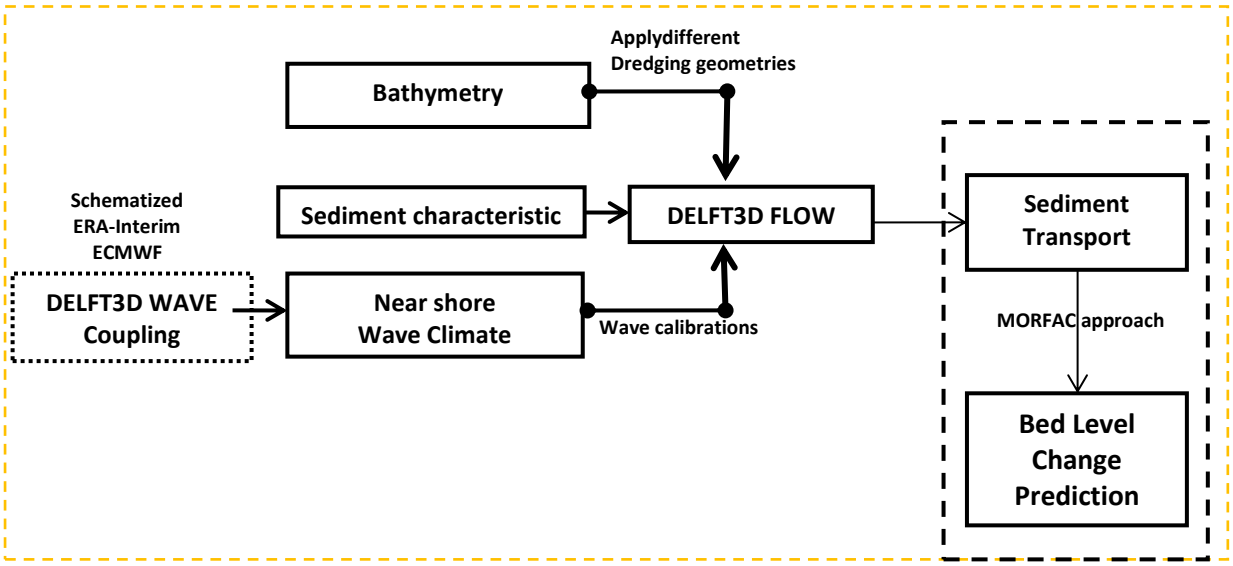


Figure 6.3.4: Flow chart of morphodynamic modelling for different dredging scenarios.

The basic flow chart given is valid for most types of morphodynamic models (Fig 6.2.4). The term 'morphodynamic model' is short for 'dynamic morphological model', where ‘morphological' means the study of shapes, in this case of the sea bed, and 'dynamic' indicates that we consider how sea bed changes as a result of processes acting on it. We call it process based modelling since we take a detailed description of the physical processes leading to sediment transport and bottom changes as a starting point. We start from a bathymetry, given on a detailed two-dimensional grid (in case of area models) or one dimension (in case of coastline or coastal profile models). Given boundary conditions for waves and currents, we predict the wave and current fields, which usually interact; together, these processes determine the sediment transport. The sediment transport gradients lead to bottom changes, which then feed back into the bathymetry, the currents and waves and the sediment transports, and so on as shown in the figure 6.2.2. Delft3D wave parameters and coefficients such as depth induced breaking; non-linear triad interactions and bottom friction were applied and checked on the wave runs. Also, different processes such as wind and wave growth, white-capping, quadruplet's interaction and refraction were activated and de-activated to understand their effect on the results of Delft3D (Table 6.2.2).

Table 6.2.2. List of the main numerical parameters used for the numerical simulations

Delft3D-flow		
Parameter	Description	Value
Dt	Time step	30 (s)
Morstt	Hydrodynamic spin-up interval for morphological changes	12 (hrs)
COMWriteInterval	Wave-Flow coupling time	30 (min)
Tkemod	Type of turbulence closure model	K-epsilon
Vicouv	Horizontal eddy viscosity	1 (m2/s)
Dicouv	Horizontal eddy diffusivity	1 (m2/s)
Vicoww	Vertical eddy viscosity	1.0E-6 (m2/s)
Dicoww	Vertical eddy diffusivity	1.0E-6 (m2/s)
Trafrm	Sediment transport formula	Van Rijn (2007)
ThetSD	Factor for erosion of adjacent dry cells	0.5 (m)
Sus	Multiplication factor for suspended sediment ref. concentration	0.50 [-]

Bed	Multiplication factor for bed-load transport vector magnitude	0.50 [-]
SusW	Wave-related suspended sed. transport factor	0.02 [-]
BedW	Wave-related bed-load sed. transport factor	0.02 [-]
Delft3D Wave		
Parameter	Description	Value
Diffraction	1600 (kg/m3)	Activated
Wind growth	1.0	Radiation stress
White-capping	0.25 (m)	Activated
		Alpha: 1
		Gamma 0.73
Quadruplets	Non-linear triad interactions	Activated
		Alpha: 0.1
		Beta: 2.2
Refraction	Bottom friction	Activated
		Type: JONSWAP
		Coefficient: 0.2 (m2 s^{-3})

In the reef area of Mount Lavinia to Colombo, a JONSWAP coefficient of 0.2 was used to represent the higher bottom friction in reef areas. Area between Colombo to Negombo default JONSWAP coefficient (0.064) was used.

Sediment transport Formula

The sediment transport and morphology module of Delft3D supports both bed load and suspended load transport of non-cohesive sediments and suspended load of cohesive sediments. Sediment transport algorithms, predominantly based on the formulations of van Rijn (1993), are added to the Delft3DFLOW hydrodynamic solver which is widely used, well tested, and well suited to modelling the three-dimensional hydrodynamics of coastal regions. The settling velocity of a non-cohesive ("sand") sediment fraction is computed following the method of Van Rijn (1993).

The suspended load transport can be determined by depth-integration of the product of sand concentration and fluid velocity from the top of the bed load layer (at about 0.01 m above the bed) to the water surface. Herein, the net (averaged over the wave period) total sediment transport is obtained as the sum of net the bed load (q_b) and net suspended load (q_s) transport rates, as follows:

$$q_{tot} = q_b + q_s \quad (2)$$

The net bed-load transport rate in conditions with uniform bed material is obtained by time-averaging (over the wave period T) of the instantaneous transport rate using a bed-load transport formula (quasi-steady approach), as follows:

$$q_b = \left(\frac{1}{T}\right).\int q_{b,t}\,dt \quad (3)$$

$$q_b = \gamma.\rho_s.d_{50}.D_*^{-0.3}\left[\acute{\tau}_{b,cw}/\rho\right]^{0.5}\left[(\acute{\tau}_{b,cw} - \tau_{b,cr})/\tau_{b,cr}\right]^{\eta} \quad (4)$$

in which, $\acute{\tau}_{b,cw}$: instantaneous grain-related bed-shear stress due to both currents and waves $\acute{\tau}_{b,cw} = 0.5\,\rho\acute{f}_{cw}(U_{\delta,cw})^2$, $U_{\delta,cw}$: Instantaneous velocity due to currents and waves at edge of wave boundary layer, $\acute{f}_{cw}$: Grain friction coefficient due to currents and waves$\acute{f}_{cw} = \alpha\beta\acute{f}_c + (1-\alpha).\acute{f}_w$, $\acute{f}_c$: Current-related grain friction coefficient, $\acute{f}_w$: wave-related grain friction coefficient, α: coefficient related to relative strength of wave and current motion, β: wave-current-interaction coefficient, $\tau_{b,cr}$: critical bed-

shear stress according to Shields, ρ_s: sediment density, ρ: fluid density, d_{50}: particle size, D_* : dimensionless particle size, γ: coefficient= 0.5, η: exponent= 1.

The net time-averaged depth-integrated suspended sand transport is defined as the sum of the net current-related ($q_{s,c}$) and the net wave-related ($q_{s,w}$) transport components, as follows:

$$q_s = q_{s,c} + q_{s,w} = \int (v.c)dz + \int \langle (V - v)(C - c) \rangle dz \quad (5)$$

in which: $q_{s,c}$: time-averaged current-related suspended sediment transport rate and $q_{s,w}$: time-averaged wave-related suspended sediment transport rate, v : time-averaged velocity, V: instantaneous velocity vector, C: instantaneous concentration and c: time-averaged concentration and $\langle \quad \rangle$ averaging over time, $\int$ the integral from the top of bed-load layer to the water surface.

Model area, domain and bathymetry

In order to achieve the resolution needed we applied an overall model and nesting to a detailed model. The large-scale wave grid with lowest resolution (Fig. 5 a, grid in blue color) was forced with measured schematized time series of wave heights, periods and directions of the Era-Interim at offshore boundary. The model output of the large-scale wave grid will then be used as the boundary conditions of the smaller hydrodynamic grid with higher resolution (Fig. 5 b, grid in green color). As a grid type, structured mesh grids were constructed. Often, wind waves are propagated to shallow water from deep water show diverse and a grid which is refined locally in the shallower area is required. As is standard practice, wave domains (overall model) were created larger than flow domains (nested detail model) to avoid any wave shadowing effects at lateral boundaries. The flow model domain covers an area of approximately 50 Km x 20km alongshore and cross-shore respectively. The depth was extended up to maximum 30m water depth. The cross-shore resolution of the computational flow grid increases from about 500 m offshore to 25 m near the coast; the alongshore resolution is 150 m. The seaward model boundary of the computation grid of the wave model is about 50 km from the coast. The computation grid of the wave model is on average four times coarser than the grid of flow model with a cross-shore resolution increases from 2000 m offshore to 200 m near the coast and an alongshore resolution is 1500 m.

Bathymetry data is divided in to offshore and near shore where near-shore data is divided into two parts: bathymetric and topographic data. For offshore bathymetry, GEBCO, 30 arc second grid resolution data is used. Near shore bathymetric data is generated by integrating existing bathymetric data from various sources such as sounding data from the hydrographic department (NARA), CCD and large scale nautical charts. The digital elevation data (90 m resolution), produced by NASA originally, was used for the near shore topographic (Slater et al., 2006). For the wave propagation from a location offshore (for example from ERA Interim data) to the near shore, GEBCO and available navigation chat data were used. For sediment transport modelling, high resolution bathymetry data between (roughly up to depth of closure) -10 to +10m with respect to MSL were used.

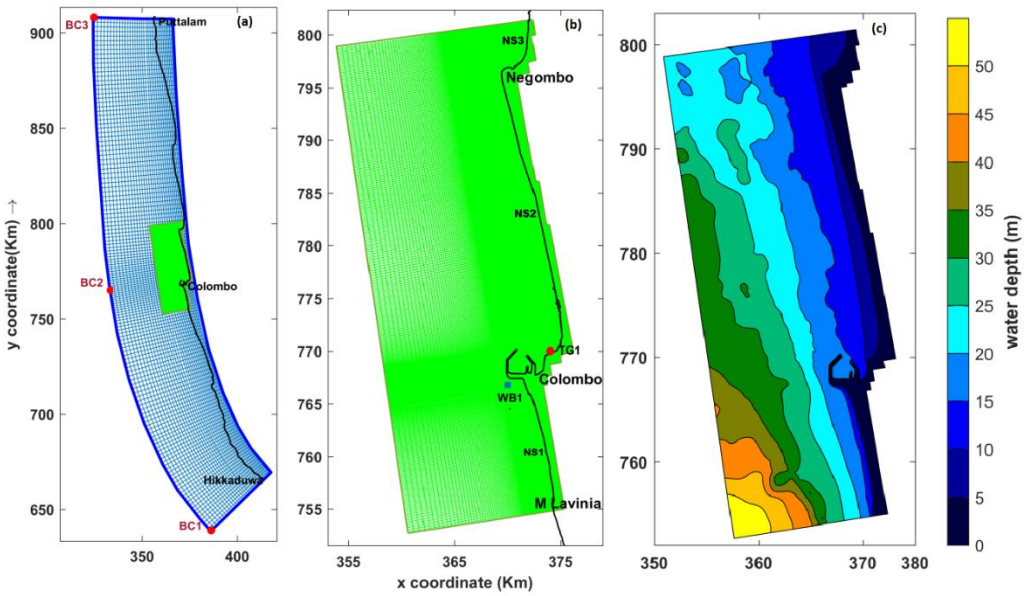


Figure 6.2.5. (a) Computational grid for wave model (blue lines), BC1-3 (red dots) was used to derive boundary conditions for offshore. (b) Curvilinear structured nesting gird for flow model (green lines), WB1 is wave measurements (blue dot) that was used to calibrate the wave model. TG1 is tide gauge data at Mutuwal, Colombo. NS1-3 are points of nearshore wave extraction (c) Bed elevations of hydrodynamic flow model (Colour bar indicates elevation: positive- water in meters w.r.t. MSL).

Boundary conditions

Water level

The model boundaries are limited to three open: North, West and South and one closed boundary: East. Due to the limited extension of the model in the cross-shore directions (North and South), a uniform value of the water level gradient was applied so called Neumann boundary. The sea boundary was forced by a harmonic water level with the schematized wave conditions (table 6.2.4). One representative tide, known as "morphological tide", was selected to minimize the computational tide, holding the best representation of the net transport during a spring-neap tidal cycle (Roelvink 1999).

Tidal constants (tidal amplitude and phase angle) from different stations around Sri Lanka by Wijeratne (2003) were applied for the Neumann and sea boundaries in the study. Tidal constants from different stations in the study area are given in the table 6.2.3

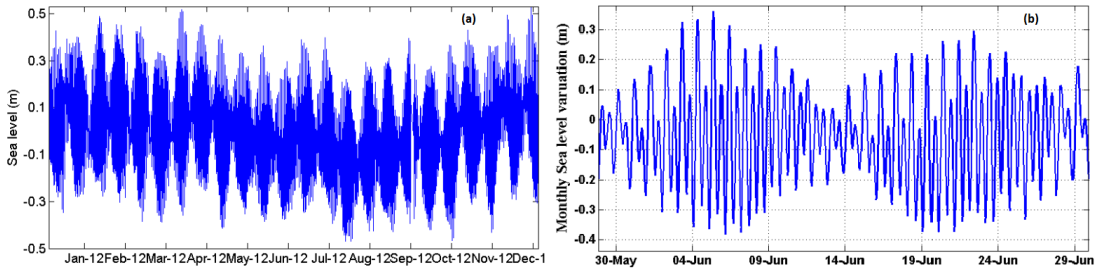


Figure6.2.6. Sea level fluctuation data from IOC monitoring sea level facility maintain by NARA, Sri Lanka for the year 2012 at Mutuwal, Colombo (a) Annual sea level variation (b) Monthly sea level variations.

The main of the sea level variation in the study areas are due to the semi diurnal tides (M2) which is considered as the main tidal constituent in Sri Lanka. The spring tide range recorded in the Bay of

Bengal is around 2.4 m while it is about 0.6 m in Colombo. It is between 0.40 - 0.60 m for mixed semi-diurnal and spring tidal range (2M2+2S2) (EMS &Pattiaratchi, 2003). Sea level fluctuation at Colombo in 2012 is shown in the figure 6.2.6.

Table 6.2.3: Tidal constants from different stations in south-west coast of Sri Lanka (where a is tidal amplitude and g0 is phase angle referred to local time). Sources: Admiralty Tide Tables, NARA. (EMS &Pattiaratchi, 2003).

Station	**M2**		**K1**	
	a(m)	g^0	a(m)	g^0
Galle	0.16	056	0.05	029
Colombo	0.18	045	0.07	018
Chilow	0.18	045	0.09	043

Wind/Wave climate

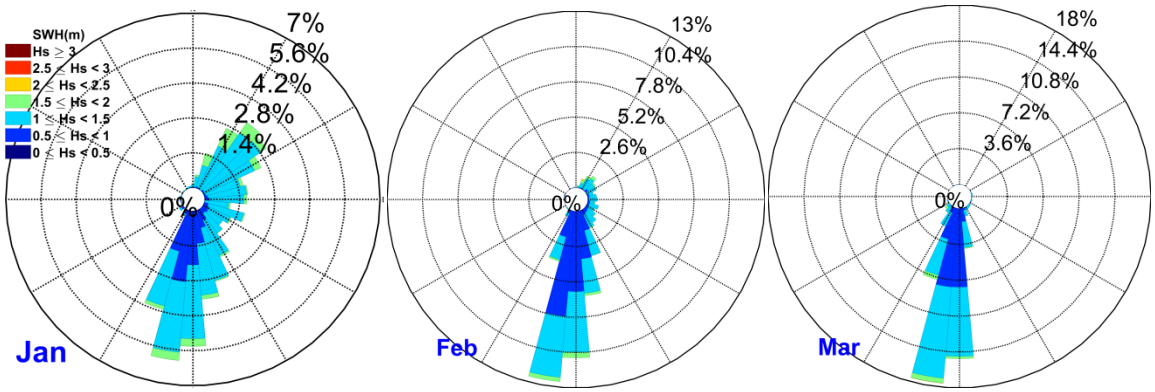
The northern Indian Ocean is characterized by bi-annually reversing monsoon winds resulting from the seasonal differential heating and cooling of the continental land mass and the ocean. The Southwest (SW) monsoon generally operates between June and October, and the Northeast (NE) monsoon operates from December through April (Tomczak and Godfrey, 2003).

ERA-Interim data were used for the off-shore wave climate analysis.

Figure6.2.7,8,9 show the monthly wave roses, time series of wave parameters and histograms of wave climate derived fromERA -interim during 2000-2017 for the off-shore location 79.75 E 7.25 N. The color of each cell in wave rose diagrams represents the significant wave high and the alignment of each the arm of gives the direction wave coming while the length of the arms of the wave roses represents the percentage of occurrence of the wave classes.

Analysis of wave climate indicates that the significant wave height varies between 0.5 m to 3 m having most probable wave heights around 1.2 m. The distribution of wave direction is mostly from 210-250 (SW) and from 30-80 (NE). Total number of wave events greater than 3 m recorded at offshore point of BC2 is 125 and these events were used to access the return periods of extreme wave events.

The SW monsoon experiences the highest probability of occurrence of higher wave events than in NE monsoon.



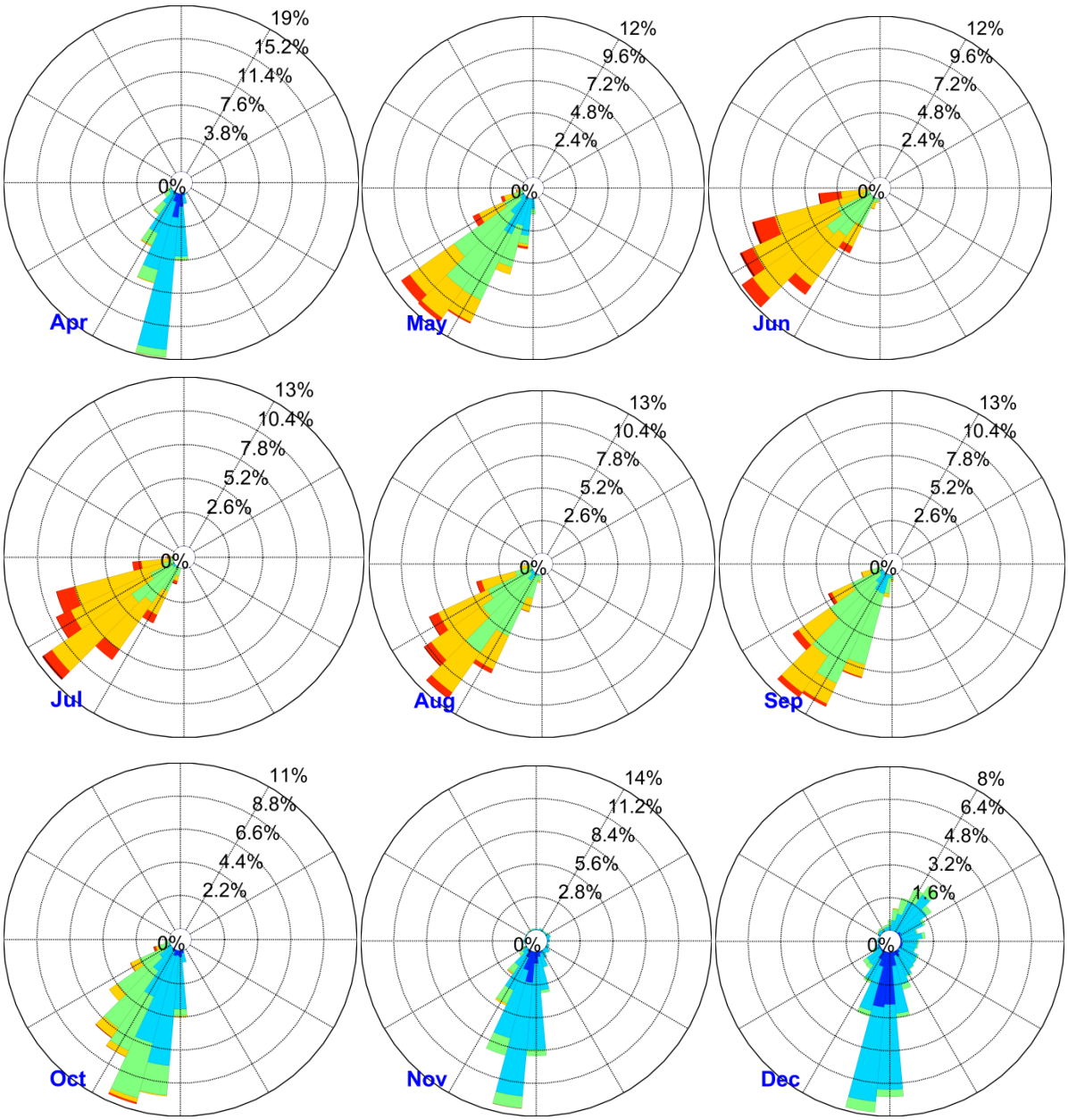
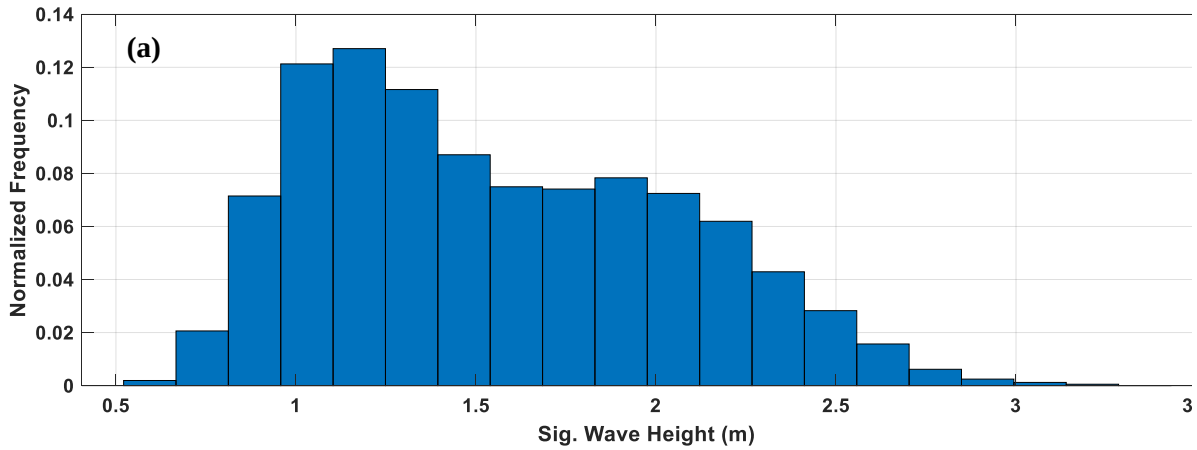


Figure 6.2. 7: Monthly Wave rose diagram, ERA-Interim during the period 2010-2017 off Negombo, 79.75 E 7.25 N.



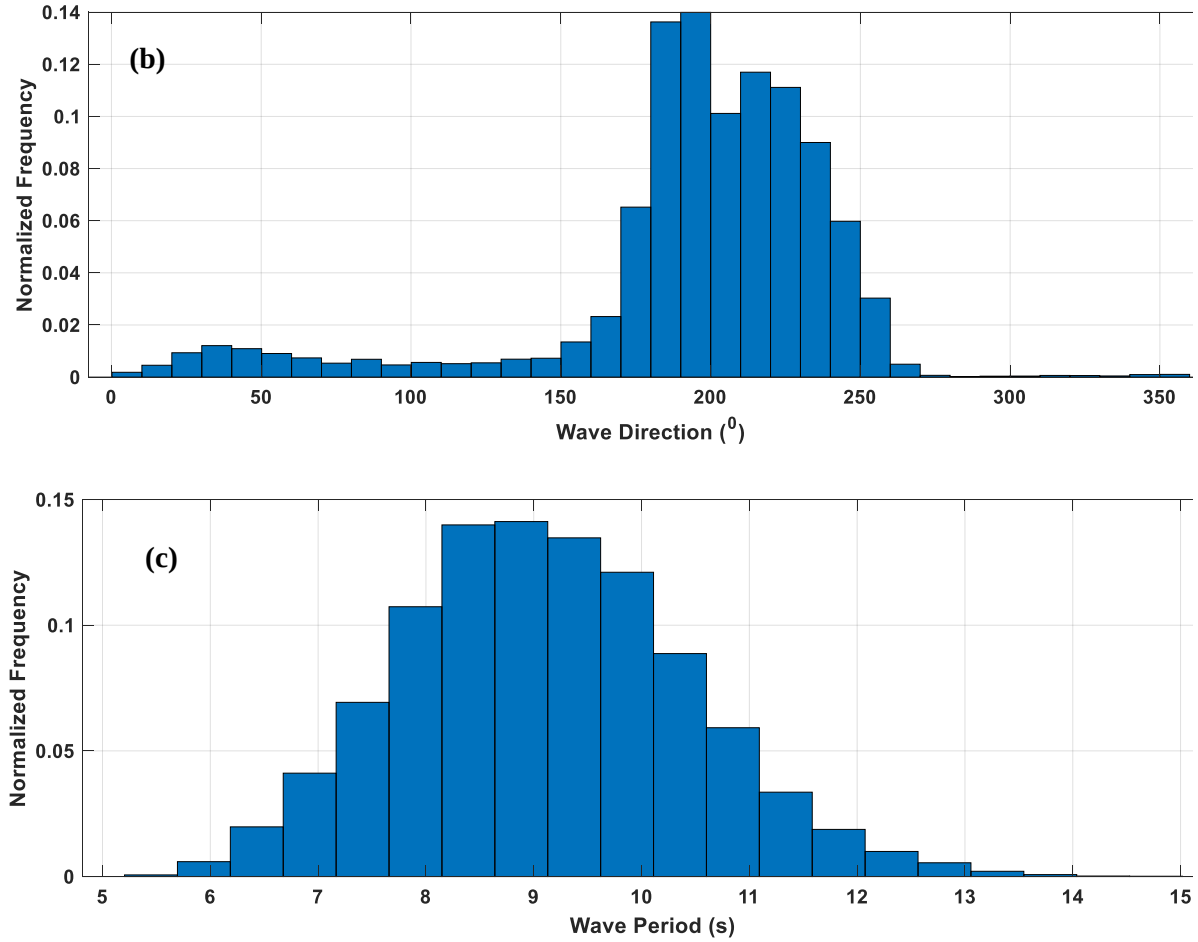


Figure 6.2.8: Normalized frequency of histograms derived from ERA-Interim during 2010-2017 off Negombo, 79.75 E 7.25 N for a) Significant wave height (m) b) Wave direction c) Wave period (s)

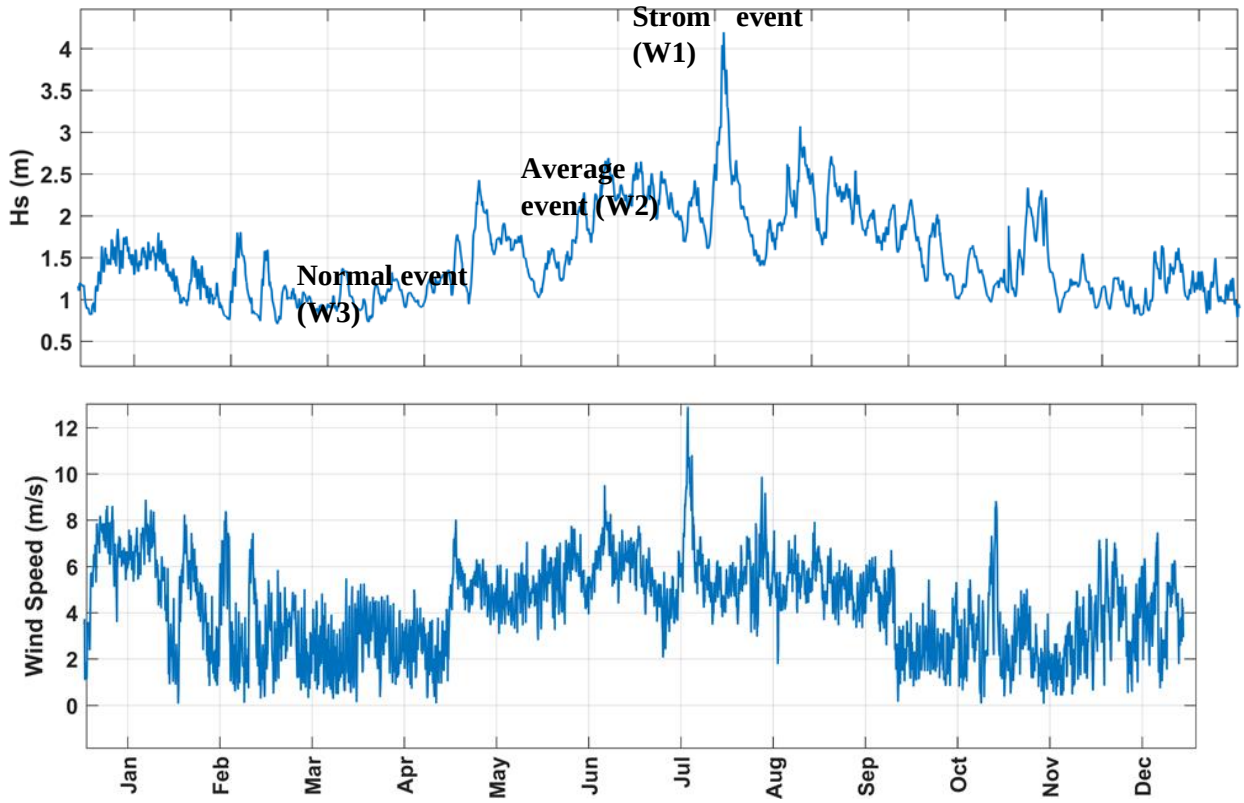


Figure6.2. 9: Time series of a) significant wave height (m) b) wind speed (m/s) from ERA-5 during the period from January 2019 to December 2019 off Negombo, 79.75 E 7.25 N.

From the observation period from January 2019 to December 2019 as shown in the figure 6.2.9, representative wave conditions which consists of three severity events such that the first event has the highest storm severity, and the subsequent events have the lowest severity. This combination allows investigating W2 and W3 are intermediate and weak events respectively. Therefore, it can be expected highest storm erosion at the beach system during W1 and the lowest impacts during W3. The numbers of events are selected in a way that to reduce computational time, while ensuring that the computed morphological developments with the reduced wave climate are similar to the full wave climate in a year. Table 6.2.4 show the resulting reduced wave climate.

Table 6.2.4: Reduced wave climate

Event	Hs(m)	Wave Direction (0)	Wind speed (m/s)	Wind direction (0)	Probability(%)	Mor. Fac
W3	1.50	230	5	240	52	336
W2	2.50	235	7	250	44	310
W1	3.00	240	10	260	4	29

A separate wave study is performed, taking into account the extreme wave climate which can be used for maintaining dune height. The study took 38 years of ERA-Interim data during the period between 1979-2017 off the coast of Negombo (79.75 E 7.25 N).From these 38 years of ERA-interim, there were 125 events having the wave heights greater than 3 meter which is considered as extreme conditions in this study. 20 of highest extreme wave events occurred are listed in the table 6.2.5

Table 6.2.5: Most extreme Significant Wave Height and their return periods occurred during the period between 1979-2017 off the coast of Negombo, 79.75 E 7.25 N.

Number	Hs-10 m (m)	w = n/38	Return Period (yr) = 1/w	Tm (s)
1	3.63	0.026	38.00	12.08
2	3.62	0.053	19.00	10.78
3	3.61	0.079	12.67	11.47
4	3.61	0.105	9.50	11.43
5	3.48	0.132	7.60	11.60
6	3.44	0.158	6.33	11.41
7	3.43	0.184	5.43	9.78
8	3.42	0.211	4.75	11.30
9	3.38	0.237	4.22	11.05
10	3.35	0.263	3.80	10.44
11	3.33	0.289	3.45	11.70
12	3.28	0.316	3.17	12.28
13	3.27	0.342	2.92	8.39
14	3.26	0.368	2.71	9.24
15	3.25	0.395	2.53	9.98
16	3.23	0.421	2.38	7.99
17	3.23	0.447	2.24	7.40
18	3.22	0.474	2.11	9.08
19	3.22	0.500	2.00	9.63
20	3.22	0.526	1.90	8.83

Table 6.2.6: Probability of Exceedance of Significant Wave Height of 46 year re-analyzed data off the coast of Negombo, 79.75 E 7.25 N.

No	Hs(m)	Wave Range (m)	Occurance(%)	Cumulative Occurance (%)	Probability Exceedance (%)
1	<0.5m	0	0	0	100
2	<1.0m	0.5-1.0	13.1	13.1	86.9
3	<1.5m	1.0-1.5	38.1	51.2	48.8
4	<2.0m	1.5-2.0	25.4	76.6	23.4
5	<2.5m	2.0-2.5	18.8	95.5	4.5
6	<3.0m	2.5-3.0	4.0	99.4	0.6

The Probability exceedancecurve for significant wave height over38 years re-analyzed data off the coast of Negombo, is shown in the figure 6.2.10.

The extreme wave condition off the coast of Negombofor various return periods is calculated for the project site (for 38 years).

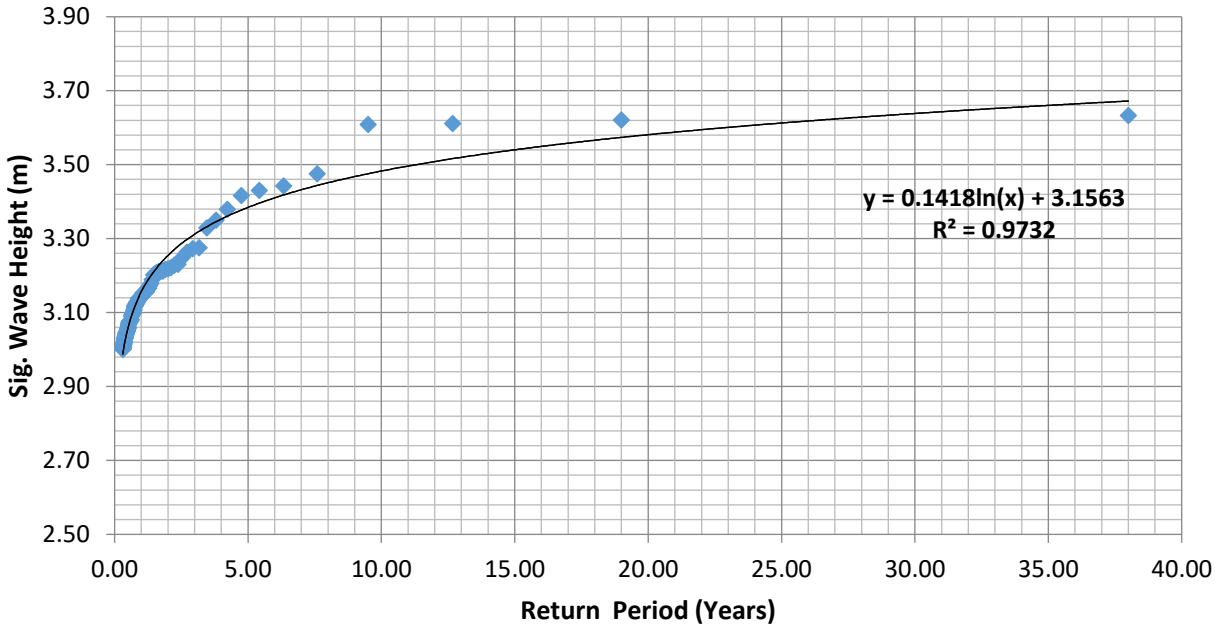


Figure 6.2.10: Return period of significant wave height of 46 year re-analyzed data off the coast of Negombo, 79.75 E 7.25 N.

6.2.3.5 Model validation

Wave measurements from 25th of August to 28th of September in 2005 were used as a validation period for the model. This period is in the Southwest (SW) monsoon season in Sri Lanka which was characterized by relative high wave activity with a storm event having a significant wave height above 3 meters. Most of the severe erosion damages in south-west part of Sri Lanka are recorded during the SW monsoons period. The most frequent waves come from the South-West, approaching the coast with an angle of about 220^0-250^0 with respect to the north (Jayathilaka, 2015). Figure 6.2.11 shows the comparison between wave characteristics from measured wave data and ERA-Interim of ECMWF forced SWAN model results at WB1, a point near port of Colombo, Sri Lanka. The significant wave height, mean wave direction and wave periods computed by the SWAN wave model are compared to the measured wave data at WB1. In addition, a statistical comparison of the numerical model results to measurements, Root Mean Square Error (RMSE); Mean Absolute Error (MAE); R2 (coefficient of determination) were calculated (table 6.2.7).

Table 6.2.7: Summary of error statistics of Wave modelling results at Colombo 19 m depth. Root Mean Square Error (RMSE); Mean Absolute Error (MAE); R2 (coefficient of determination)

Index	Sig, Wave Height (m)	Mean Wave Direction (deg)	Mean wave Period (s)
RMSE	0.26	9.2	0.6
MAE	0.21	7.5	0.5
R^2	0.88	0.29	0.49

Overall, the model validation shows a moderate performance. The coefficient of determination of computed for significant wave height gives a good correlation to measured data with a lower root mean square error, although the peak of the storm on the 5th of September 2005 is slightly underestimated. The model reproduced rather well significant wave heights. Even though there are some discrepancies in wave direction and mean wave periods, the order of magnitude and the overall pattern of the time series match. The main reason for the discrepancies can be attributed to effect of offshore wind field and near shore bathymetry. Wind plays an important role in the flow field and circulation patterns, e.g., it creates a water level change and wind driven current, feeding energy into waves via Miles mechanism (Bakhtyar 2016, Phillips, 1957). Due to poor wind field resolution, we applied interpolated coarser wind field in to wave model which likely does not correspond with the wind field for the entire study area. Indeed, the inaccuracies in the variable wind field can affect the wind set up (Elias et al.2000). Presence of the reef area of Mount Lavinia to Colombo, a JONSWAP coefficient of 0.2 was used to represent the higher bottom friction in reef areas. Area between Colombo to Negombo default JONSWAP coefficient (0.064) was used.

The validated wave model was published in Journal of the National Science Foundation of Sri Lanka, 2020 (Jayathilaka, R.M.R.M ,2020).

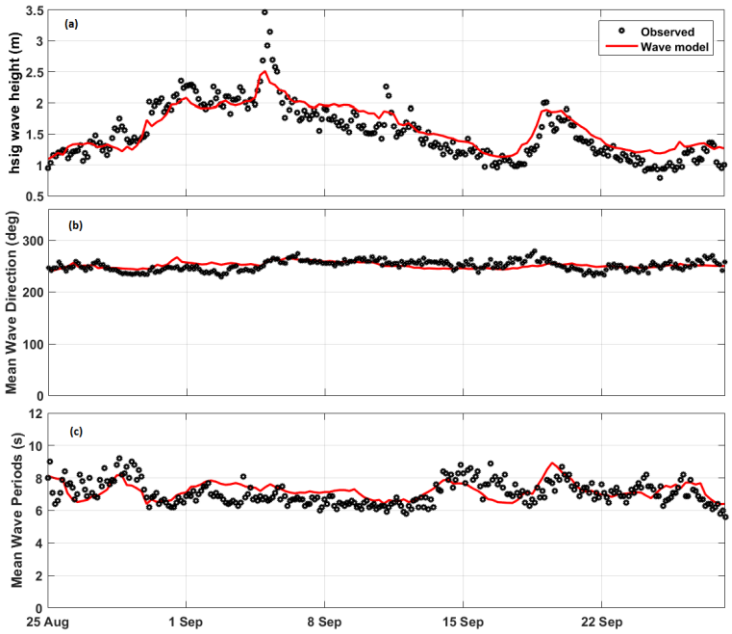


Fig. 6.2.11: Comparison between wave characteristics from measured wave data and ERA-Interim of ECMWF forced SWAN model results at point WB1 (near Colombo port at 19 m depth). (a) Significant wave height; (b) mean wave direction; (c) mean wave periods.

6.2.3.6 Configurations - Sand Extraction Trench

Bathymetric data during the post- dredging period in the study area are hardly found in the literature or may not be published by the relevant authorities. Therefore, we calculated an average dredging thickness based on the sand extraction volume used for reclamationworks for port city project.

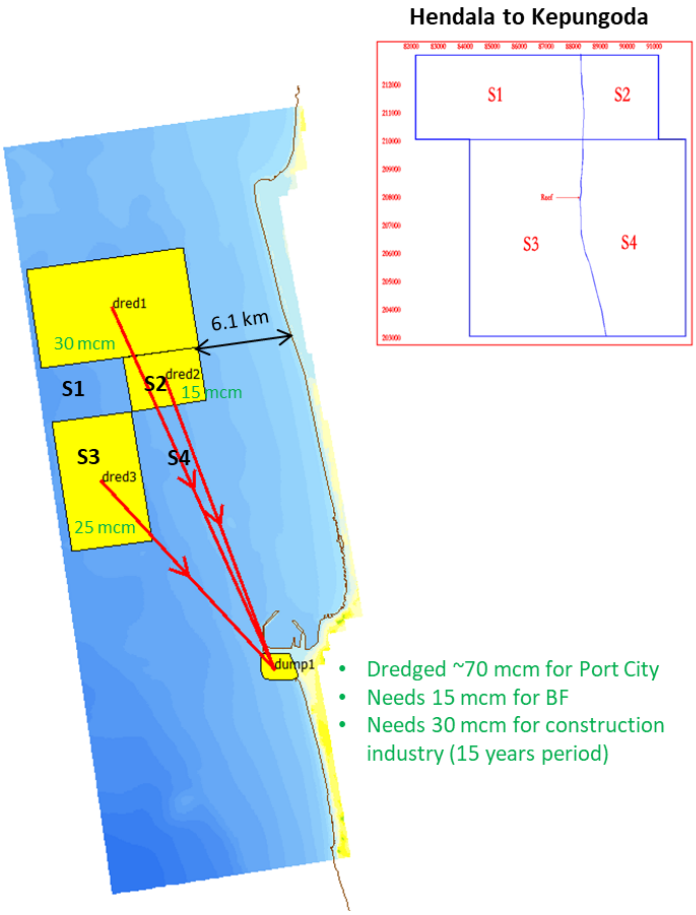


Figure 6.2.12: Configurations - Sand Extraction Trench

Moreover, the Delft3D model has been used to simulate the impact of seven different sand extraction trench configurations. However, we were able to complete the trench configurations 1 to 4 during the year 2020.

1.Reference situation (i.e. without deepening)
2.Sand trench with a uniform depth of 1 m
3.Sand trench with a uniform depth of 2 m
4.Sand trench with a uniform depth of 3 m
5.Sand trench with a non-uniform depth and with the same volume as sand trench #3
6.Sand trench #3 without the narrow part of the deepening
7. Sand trench with a non-uniform depth and with a comparable volume as sand trench #2

6.2.4 Results

6.2.4.1 Analyze the wave climate variability

The northern Indian Ocean is characterized by bi-annually reversing monsoon winds resulting from the seasonal differential heating and cooling of the continental land mass and the ocean. The SW monsoon generally operates between June and October, and the NE monsoon operates from December through April (Tomczak and Godfrey, 2003). The transition periods are termed the first inter-monsoon (May) and the second inter-monsoon (November). We studied 40 years (from 1979 to 2019) of ERA-Interim data to schematize the wind/wave climate for boundary conditions. Figure 6.2.7 shows the wind/wave roses off Colombo. In which the length of the arms of the roses represents the percentage of occurrence of the situation and the color of each cell represents the magnitude. The alignment of each the arm gives the direction of wind/wave.

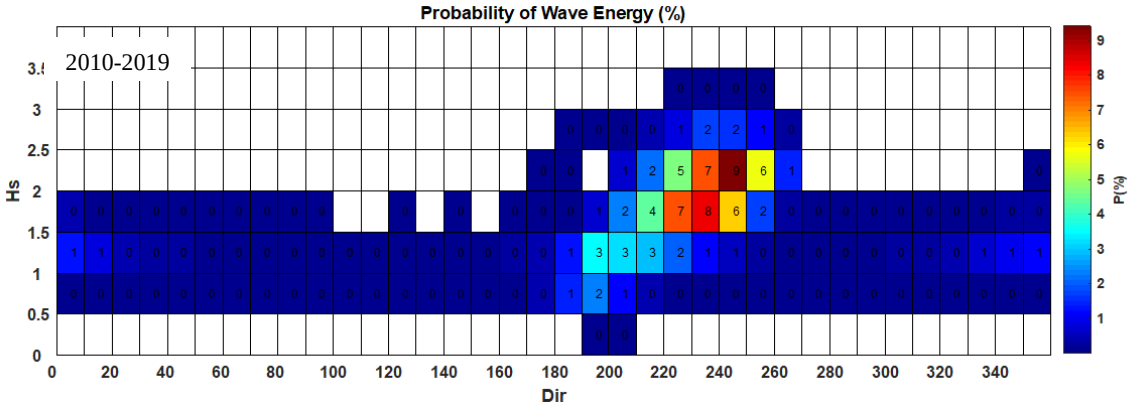
According to the wind climate study, wind is coming from NE direction from November to March with the angle 40^0-60^0while it changes to SW direction with the angle 220^0-240^0 from May to September. During SW monsoon, the wind speed varies between 7-11 m/s while it varies between 1-5 m/s during NE monsoon. The total number of wind/ wave events studied here is 54053 during 1979 and 2015. Our wind analysis for extreme events found 43 and 65 events for wind speeds greater than 12 m/s at BC2 and BC3 respectively. More than 95% of such events occurred during SW monsoon period.

Analysis of wave climate indicates that the significant wave height varies between 0.5 m to 3 m having most probable wave heights around 1.5 m. The distribution of wave direction is mostly from 210^0-250^0 (SW) and from 30^0-80^0 (NE). Total number of wave events greater than 3 m recorded at offshore point of BC2 is 149 and we found no such an extreme waves events at BC3. The SW monsoon experiences the highest probability of occurrence of higher wave events than in NE monsoon.

To analyze long-term wave climate variability and short-term wave climate variability, the yearly maximum, minimum and average of parameters from wave, wind and temperature data sets were analyzed from 1979 to 2019 and from 2010 to 2019 respectively.

Table 6.2.8: Long term (1979-2019) and short term (2010-2019) wave climate variability

	1979-2019			2010-2019		
Parameter	Yearly maximum	Yearly minimum	Yearly average	Yearly maximum	Yearly minimum	Yearly average
Significant wave height (m)	3.8101	0.4788	1.3850	3.2712	0.4788	1.3925
Wave period (s)	15.1885	5.0131	8.8386	15.1885	5.3645	8.8581
Wave direction (SW monsoon) (^{0})	NA	NA	233.5	NA	NA	233.3
Wind speed (m/s)	10.90	NA	4.44	11.25	NA	4.50
Wind direction (SW monsoon) (^{0})	NA	NA	248.2	NA	NA	248.3
Wave Energy (Kw/m)	NA	NA	2.2778e+05	NA	NA	2.2992e+05



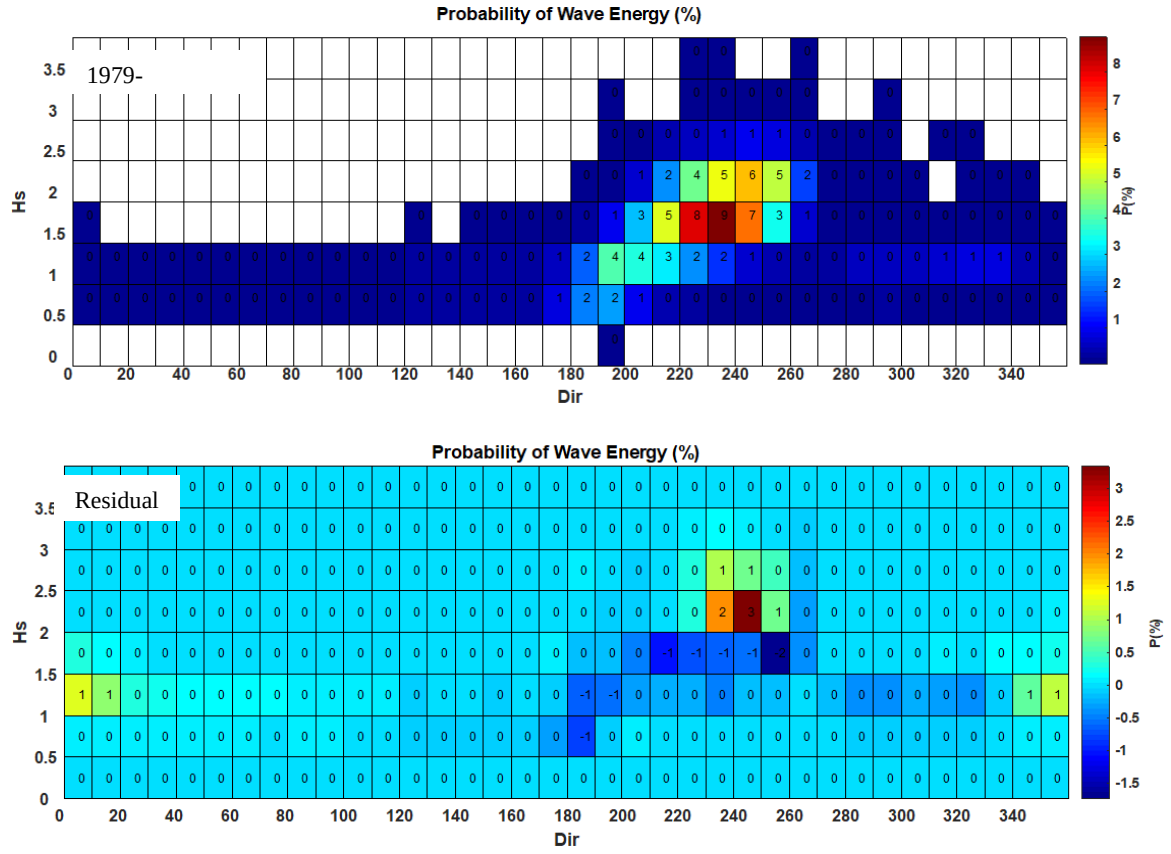


Figure 6.2.13: Residual change between short term and long-term wave energy flux.

The residual change between short term and long-term wave occurrence probability (%) was analysed (Figure 6.2.13). It is clear that the short-term wave height bins which are more than 2m have increased their occurrence probability comparing with the long-term trend. Most of the higher probabilities occur in the Southwest monsoon period.It is clear that during the Southwestmonsoon the wave heights which are greater than 2m have increased the wave energy within theshort term of period and the wave heights which are less than 2 m have reduced the waveenergies. Also, some waves between the heights of 1-1.5m appear during the Northeast monsoonin the short term period though it was not experienced in long term period.

6.2.4.2 Impact of the trench on waves and currents

This section discusses the impact of the trench on waves and currents the results from the model simulations. We focus on three wave condition: P1, P2 and P3 (see Table 9).

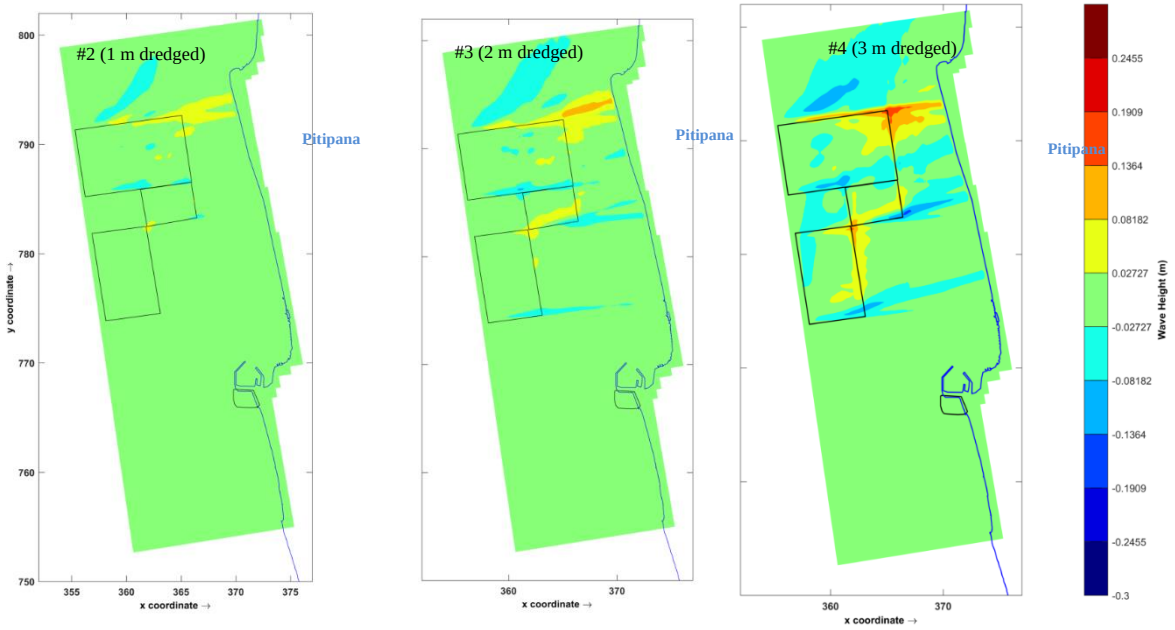
Table 6.2.9: Reduced wave event

Wave condition	Hs(m)	Wave Direction (0)	Wave Period (s)	Wind speed (m/s)	Wind direction (0)
P1	3	230	9	10	245
P2	1.7	230	7	5	245
P3	0.6	230	5	30	245

We chose three probable wave heights mostly occurred in the SW monsoon. For practical reasons we will only discuss the impact of the trenches with uniform depths of 1, 2 and 3 m relative to the reference geometry (Nodredging).

Table 6.2.10 : Simulation results

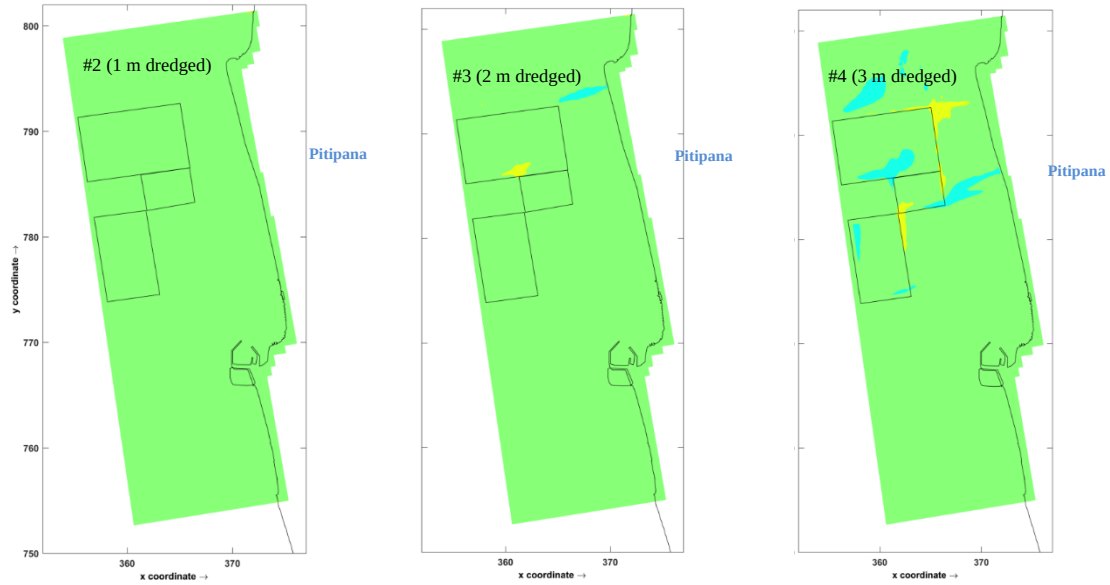
Wave condition	P1			P2			P3		
Trench Scenario	#2	#3	#4	#2	#3	#4	#2	#3	#4
Max.Wave height (m)	.05m	0.1m	0.2 m	-	<0.05m	<0.05m	-	-	-
Max.Currents (m/s)	<0.05 m/s	0.05 m/s	0.12 m/s	-	-	<0.05 m/s	-	-	-



Wave condition: P1

Wave condition: P1

Wave condition: P1



Wave condition: P2

Wave condition: P2

Wave condition: P2

Figure6.2.14 Difference in the magnitude of the wave height (m) between simulations #4,#3,#2 and #1 (reference case without dredging) at different wave conditions. The solid lines the extent of the sand extraction trench.

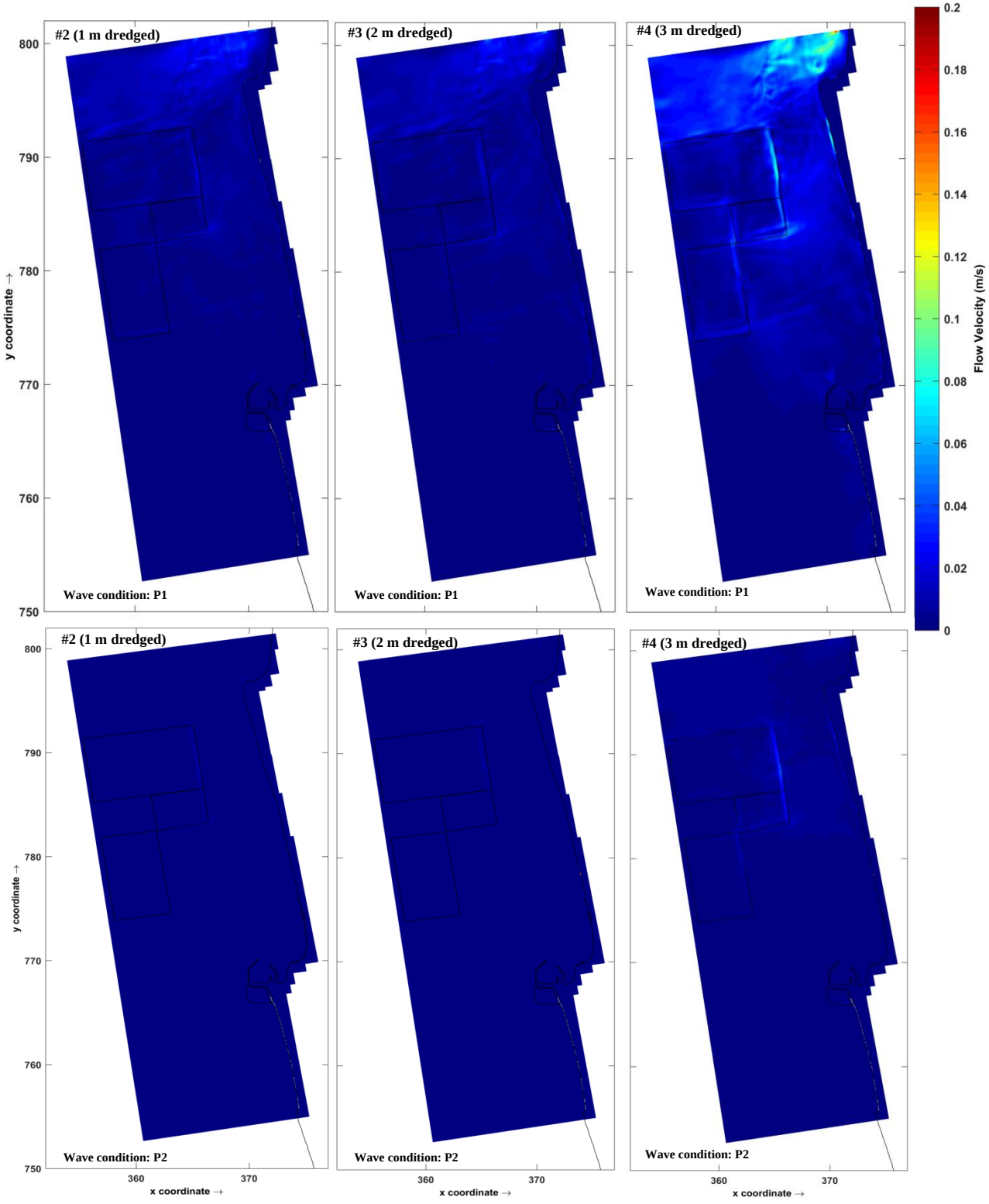


Figure 6.2.15 Difference in the magnitude of the flow velocity (m/s) between simulations #4,#3,#2 and #1 (reference case without dredging) at different wave conditions. The solid lines the extent of the sand extraction trench.

Discussion

The main contribution of this work is to derive a modeling approach to determine the impact of dredging on waves, currents, sand transport rates and morphologyon adjacent coastal environment of Negombo-Wadduwa coastline, Sri Lanka. To this end, we will establish a process-based coastal area morpho-dynamic model for the western region of Sri Lanka and calibrate the model against the measured wave data. The calibrated model was applied to determine the coastal system response to waves, currents, sand transport rates and morphology derived under different sand extraction trench geometries.

The simulations show that the waves become higher due to the deepening, as bed friction is lower because the water depth is larger (table 10). This effect becomes more important for deeper trenches (scenario #4). This is due to the fact that relatively less wave energy is dissipated due to bottom friction related to the increased water depth. The impact is strongest at the location of the trench and of lesser importance in the near-shore zone where not dissipation due to bed friction, but dissipation due to wave breaking is the dominant process.

Themaximum increase, in case of 3 m deepening (scenario #4), is about 0.2m at the trench and 0.1m near the coast of Pitipana. However, we see that in case of 2 m deepening (scenario #3) with higher wave conditions (P1) and 3 m deepening (scenario #4)2 m deepening (scenario #3)(P2) give more or less similar impactnear the coast. In the case of other scenarios impacts impact near to the coast is lesser.The near coast to the northward of the dredging area is strongly effect the wave height change. This is due to the incidence of severe waves during the Southwest monsoon, and this is less importance for waves coming from the Northeast. Moreover, we see that the wave height do not change southward of the dredging area due to deepening, therefore no or less impact near the coast between Wadduwa to Modara.

The changes in flow velocity are maximum 0.12 m/s of the peak current velocityn case of 3 m deepening (scenario #4) with higher wave conditions (P1), at the coast the waves are maximal 0.2 m higher.The maximum flow velocity increase is 0.05 m/s in the trench an a few cm's near the coast for in case of 2 m and 1m deepening.

The flow velocities are impacted by different processes. The decrease in bed friction leads to higher velocities inside the trench. In general the velocities increase in the deepening due to the decreased bed friction. Simulations #4 and #3 show similar effects of the deepening, but the impact is smaller as depths are smaller. At the edges of the trench the velocities suddenly increase (during outflow) as the result of mass continuity. Local variations in trench geometry affect the flow velocities locally as well, especially edge of the sand extraction trench.

Other possible reasons for on-going coastal erosion:

Coastal interventions.

The southern breakwater arm of Colombo South Port (2 km long) shows the strong effect on transport gradient. The shoreline upstream of the structure accretes rapidly and coast downward shows rapid erosion. However this downstream section (between Modara and Dikkovia) is protected by hard measures such as detached breakwater and series of groynes. The seaward end of the breakwater will be in about 18 m depth of water, which is far deeper than the depth of closure where most of sediment transport occurs. Therefore, a significant proportion of sand transport is captured by the breakwater arm in which accumulate against the breakwater. Over time the area of accumulation will extend both seawards and southwards along the coast where the ongoing port city development project is located. The behavior on the down drift side of the breakwater is depending on the process of the building of the long-shore current. The slow building of the long-shore current leads the long area of extends for erosion. This region between Dikkovita and Uswatakeiyawa is identified as a severely eroding coastline (CCD, 2004; Jayathilaka, 2015). Master Plan for Coast Erosion Management Summary, the erosion

rate was identified as 2.5 m/year for 70% of the coastline from Palliyawatte to Uswetikeiyawa. The erosion rate is controlled by the groynesbetween 2005-2010 and the sand nourishment between 2010-2016. However this erosion is transferred to further northward after 2016.

River sand mining.

According to CCD (2004), the transport gradient along the southwest coast has balanced by the sand supply from the rivers. Furthermore, the high deficit in the littoral budget due to sand mining in the MahaOya causes the severe erosion north of Negombo. Studies conducted by CEA and the CCD in 1992-1997 estimated a total sand transport of 400,000 m3/year and the annual volume of sand mined from Kelani River to be 800,000 m3/year. Based on data from previous studies on sand supply to the coast and the Coastal Resources Management Project-1999, the estimated sand supply to the coast is 100,000 m3/year representing a significant decline. A study conducted in 1999 estimated that the sediment outflow from the Kelani River would further decline by 40% in the next twelve years (CCD, 2004). Decrease in sand supply from the Kaleniriver is said to accelerate the down drift erosion north of the Kelani river mouth (CCD, 2004).

Extreme waves (monsoon) and relative sea-level rise.

Analysis of wave climate indicated that the Southwest monsoon has greater influences having the highest probability of occurrence of higher wave events on the near-shore wave climate thus sediment transport in the study area. More than 95% of the extreme events occurred during the SW monsoon periods.

Also It is identified the erosion due to sea level rise will be contributory factor which may occur in the sediment budget.

Conclusion and Recommendation

In Sri Lanka, offshore sand mining mainly takes place between the established beyond 8 m depth contour and 3 km from the coast with the dredging depth to be limited to 3m from the surface (Port City Development Project). This sand demand could rise in the near future in light of a possible increase in coastal erosion/sea level rise and the construction of large infrastructural works. To meet the potential increase in sand demand, it will be necessary to mine on a larger scale (deeper and wider) than current practice. However, our model results yield that there will be impact on the near coast if the dredging depth is 3m and nearest to the coast. Therefore, In the near future, a sand mining strategy needs to be developed for Sri Lankan water which includes choices about mining locations (offshore distance and depth) and quantities (sand volume/sub surface layers). Such a strategy requires knowledge on the depth of closure (h_{doc}) in an area where the wave climate is likely to have little effect on bottom sediments. The sand movement due to longshore sand transport occurs at depths less than the h_{doc}. However, the closure depth value is mainly depending on the wave climate and cross-shore profile steepness.

However, according to the University of Moratuwa and the GSMB, dredging is not economically viable when depths exceed 20 m and this seems to be case in the east coast where many locations have depths exceeding 20 m, though some countries such as France and Japan do not permit mining activities at depths $\leq$20 m (Hilton 1994; Hommes et al. 2007). In The Netherlands, offshore sand mining mainly takes place between the established NAP -20 m depth contour (NAP is a vertical datum close to mean sea level at the Dutch coast) and 22 km from the coast.

Financial Allocation (Rs) :200,000.00

Financial progress (%): 97 Physical Progress (%): 90

6.3 Prospecting sand resources in Offshore ,Galle

Officers :Dileka Samaranayake
Division : National Institute of Oceanography and Marine Sciences, NARA
Duration : 2020 (January to December)
Budget(FY 2020) : LKR 0.3 Mn
Location : Galle
Source of funds : NARA

Introduction

Due to rapid development in construction industry since 2009 the demand for the construction materials including sand has grown up enormously resulting shortage of the supply. The crisis led to illicit sand mining in major river banks which arise many environmental issues.Therefore there is an urgent need for an alternative for river sand. Offshore sand is a promising alternative for river sand.

Currently Sri Lanka Land Reclamation and development cooperation use offshore sands for constructions after purification. As the demand for the sand arises day by day they seek for other locations to extract sand which is suitable for construction purpose.

Since the extraction process in deep ocean is not economically feasible, this study intended to study the construction sand resources in the continental shelf in Galle area.

Objectives:

- To prospect the sand resources in Galle area
- To study the chloride, shell and heavy mineral content in offshore sand

Sample/Data collection:

Sediment sampling

The offshore field visits from Galle to Ratgama were carried out from February to September 2019.

Sub bottom profiling

Sub bottom profiling survey could not be completed for the study area due to the Corona pandemic and unfavorable weather conditions.

However, a preliminary feasibility study (Sub bottom profiling survey) was carried out in Northeastern offshore area, off Chundikulam by occupying the sub bottom profiler INNOMAR SES 2000 .

Based on the results, the survey will be further extended in Northeastern continental shelf of the Northeastern area in 2021.

Results
Grab samples
Grain size and distribution characterization
Based on the sediment sample analysis and visual observations carried out in 2019, surface geology map was prepared for the study area (Figure 6.3.1). The area covered was 35-40 km^2. All the parameters were calculated based on Falk and Ward(1957) classifications.

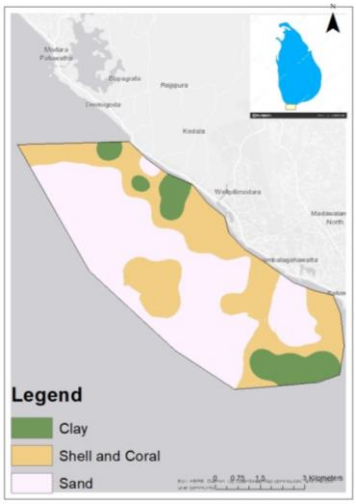


Figure 6.3.1 Study Area

The results of the sand size characterization are summarized below.

Table 6.3.1 The results of the sand size

Parameter	Result
Mean Grain size	0.073-1.25 mm Recommended Range : 0.5mm to 2 mm
D50	0.07mm to 1.8mm Recommended Range : Around 0.6mm
Sorting	Moderately well sorted

A distinct sand bed was indentified with the width of 105 km and ~6.5km length. It is located beyond a shell and coral patch. The deposit located approximately 3-5km from the coastal line.

Shell and coral percentage

The shell and coral percentage for the size (mm)>10 was less than 5% and the size 5mm to 12mm is around 12% which is compatible with the standards.

Chloride percentage

The chloride percentage was 2.8 % by the weight of the sand while the recommended range is 0.075%(Dias et al., 2008). However, appropriate remedies such as piling up and artificial washing could reduce the chloride content.

Heavy Mineral content

The heavy mineral content varied from 0.12 to 12% by weight. The minerals identified were Ilmanite,Zircon Rutile and Garnet.

Sub bottom profiling

The results of the sub bottom profiling in Chundikulum area indicate the sand layer in the surveyed area was varied from 0.5m to 4 m. However, further studies should be done to analyze the sand quality of the deposit.

Discussion and conclusion

Bathymetry of the study area varies from 0m to 9m within the 500m from the coastline and within 2.5 km from the coast line 0-38 m depths recorded (Based on bathymetry map generated by NARA).

However, the depth of the continental shelf around the Gin River shows much shallower, showing the influence of the sediment carried by the river.

A distinct sand bed was identified which extends length of ~6.5km with 1.5km width. All the other parameters except the chloride content were compatible with the standards.

Further,the deposit is located beyond 15m depth and 2.5km from the shore indicating the deposit can be mined according to the regulations practice in Sri Lanka. However, a sub bottom survey should be done in the area to confirm the quantity of the sand deposit which could not complete during 2020 because of the Corona pandemic .

Financial Allocation (Rs) :200,000.00

Financial progress (%): 97 Physical Progress (%): 80

6.4 Monitoring the Aggregation of Micro-plastics in Coastal Waters around Sri Lanka

Officers : W.R.W.M.A.P. Weerakoon
Division : National Institute of Oceanography and Marine Sciences, NARA
Duration : 2020 (January to December)
Budget(FY 2020) : LKR 0.2Mn
Source of funds : NARA

Introduction

Marine pollution, in particular, micro-plastic pollution is an emerging threat in Sri Lanka, which demands continuous assessments and monitoring, especially in the sensitive eco-systems such as coral reefs, since micro-plastics could carry toxic chemicals, result in bio-accumulation, and abolishcoral reefs, that may bring lethal impacts to marine biodiversity. Thus, this project (an extension of 6.4, 2019) further examined the degree of micro-plastic pollution, in particular floating micro-plastics (in the range: 0.3–5 mm) in surface waters around two major coral reefs in Sri Lanka; The Bar-Reef marine sanctuary(North-western coast), and the Pigeon Island national park (Eastern coast),

Objectives

To assess (1) abundance, (2) categories, (3) sources of pollution, (4) weathering status and (5) aggregation of floating micro-plastics, that have been accumulated in surface waters in aforesaid ecosystems.

Key Findings

(1) Abundance of micro-plastics:The average abundance of floating micro-plastics (0.3–5 mm) at the Bar-Reef marine sanctuary, ranged from 0.54 to 30.43 particles per square meter (PSM) in 2018, 0.60 to 30.81 PSM in 2019, and 0.65 to 32.43 PSM in 2020, whereas the average abundance of floating micro-plastics at the Pigeon Island national parkvaried from 0.24 to 16.83 PSM in 2018, 0.26 to 17.09 PSM in 2019, and 0.27 to 18.23 PSM in 2020 (Tables 1, 2 and 3). At all monitoring circumstances, the abundance of floating micro-plastics at the Bar-Reef marine sanctuarywas notably higher, compared to the concentrations recorded from the Pigeon Island national park.

Table 6.4.1.Micro-plastic pollution [average annual abundances of particles (0.3 mm – 5 mm), PSM] in surface waters at Bar-Reef marine sanctuary in 2018 and 2019.

Micro-plastic category	2018		2019	
	Minimum	Maximum	Minimum	Maximum
Fragments	0.31 (57.41%)	10.73 (35.26%)	0.34 (56.67%)	10.48 (34.01%)
Foams	0.12 (22.22%)	10.92 (35.89%)	0.14 (23.33%)	11.54 (37.46%)
Films	0.05 (00.09%)	05.23 (17.19%)	0.05 (08.33%)	04.75 (15.42%)
Thread-likes	0.04 (00.07%)	02.34 (07.69%)	0.04 (06.67%)	03.07 (09.96%)
Thin-fibers	0.02 (00.03%)	01.21 (03.98%)	0.03 (05.00%)	00.97 (03.15%)
Total particles	0.54 (100%)	30.43 (100%)	0.60 (100%)	30.81 (100%)

Table 6.4.2.Micro-plastic pollution [average annual abundances of particles (0.3 mm – 5 mm), PSM] in surface waters at Pigeon Island national park in 2018 and 2019.

Micro-plastic category	2018		2019	
	Minimum	Maximum	Minimum	Maximum
Fragments	0.10 (41.67%)	8.31 (49.38%)	0.11 (42.31%)	8.34 (48.80%)
Foams	0.04 (16.67%)	6.23 (37.02%)	0.05 (19.23%)	6.29 (36.81%)
Films	0.04 (16.67%)	2.14 (12.72%)	0.04 (15.38%)	2.31 (13.52%)
Thread-likes	0.04 (16.67%)	0.12 (00.71%)	0.04 (15.38%)	0.12 (00.70%)
Thin-fibers	0.02 (08.33%)	0.03 (00.18%)	0.02 (07.69%)	0.03 (00.18%)
Total particles	0.24 (100%)	16.83 (100%)	0.26 (100%)	17.09 (100%)

Table 6.4.3. Current level of micro-plastic pollution (average abundance, 2020) in surface waters at Bar-Reef marine sanctuary and Pigeon Islands national park.

Micro-plastic category	Bar-Reef marine sanctuary		Pigeon Islands national park	
	Minimum	Maximum	Minimum	Maximum
Fragments	0.37 (56.92%)	13.72 (42.31%)	0.12 (44.44%)	9.54 (52.33%)
Foams	0.16 (24.62%)	09.53 (29.39%)	0.05 (18.52%)	4.76 (26.11%)
Films	0.07 (10.77%)	04.65 (14.34%)	0.04 (14.81%)	3.51 (19.25%)
Thread-likes	0.03 (04.62%)	03.11 (09.59%)	0.04 (14.81%)	0.34 (01.87%)
Thin-fibers	0.02 (03.08%)	01.42 (04.38%)	0.02 (07.41%)	0.08 (00.44%)
Total particles	0.65(100%)	32.43(100%)	0.27(100%)	18.23 (100%)

(2) Aggregation of micro-plastics:The results indicate a rise in the abundance of floating micro-plastics in both coral reefs, where in 2019, the abundance of floating micro-plastics at Bar-Reef marine sanctuaryhas been increased at least by 9.47%compared to 2018, whereas that in Pigeon Island national park has been ascended at least by 5.94%. In 2020, the average abundance of floating micro-plastics in Bar-Reef marine sanctuary have been increased at least by 7% whereas that in Pigeon Island national park has been risen at least by 4% compared to 2019.

(3) Categories of Micro-plastics:The majority of floating micro-plastics found inBar-Reef marine sanctuary and Pigeon Island national park were fragments, and were secondary micro-plastics, where

most of the floating micro-plastics were weathered particles of hard plastics. The second major category of floating micro-plasticsfound were foams, threads and thin fibers.

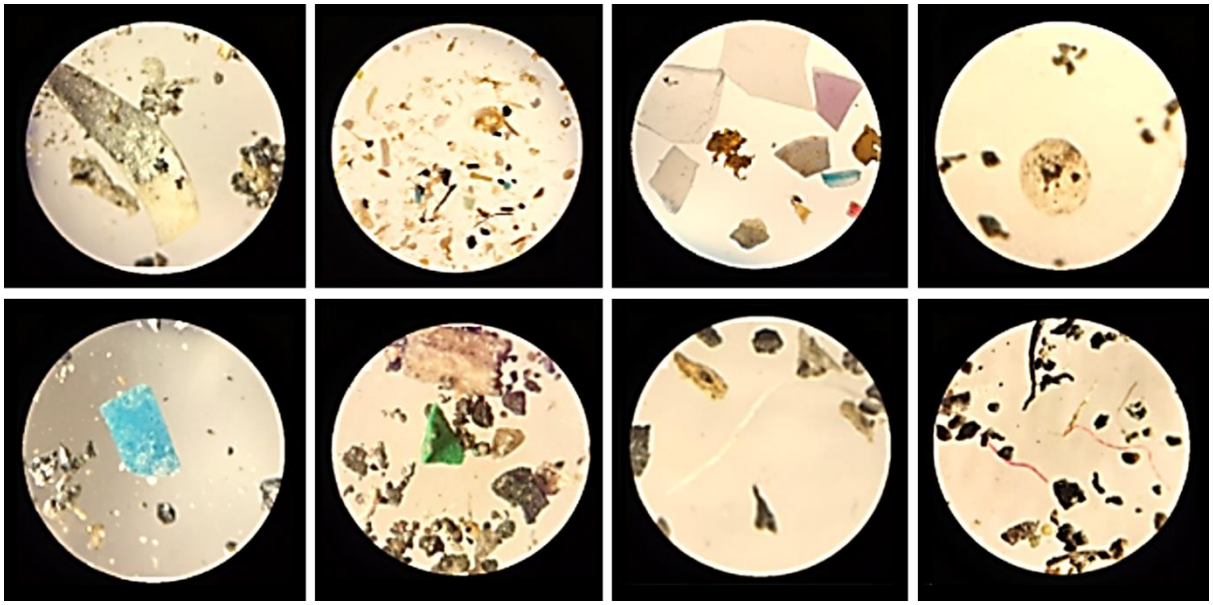


Figure6.4.1.Different categories of micro-plastics observed under the microscope

Fishing in Bar-Reef marine sanctuary in very close proximity to the reef could be a major reason for the generation of abandoned, lost or discarded fishing gear (ALDFG) directly on the reef, which could impose severe issues such as ghost fishing, depletion of fish resources and loss of biodiversity. The relatively higher concentrations of thin fibers and thread-likes in the Bar-Reef marine sanctuary indicates the pollution of waters around the coral reef with the debris of fishing gear and textiles.This study provides the first evidence on the aggregation of floating micro-plastics in waters around coral-based eco-systems in Sri Lanka.

Suggestion for Policy Implications

Since the pollution levels are increasing in both Bar reef and Pigeon Island, attention must be paid to minimize the generation of waste from single-use plastics and polythene, fishing gear and textiles. Both waste water treatment and solid waste management must be further improved to minimize contamination of waterbodies. A proper management plan is suggested for the management of ALDFG, while fishing around coral reefs must be controlled.

Financial Allocation (Rs) :200,000.00

Financial progress (%): 90 Physical Progress (%): 80

6.5 Assessment of Climate Change Impacts on the Ocean Environment: Impacts of Temperature, Salinity and Water Level on Coral Reefs in the East and the West Coasts of Sri Lanka

Officers : Mr.H.B.U.G.M. Wimalasiri and Mr. W.R.W.M.A.P. Weerakoon
Division : National Institute of Oceanography and Marine Sciences, NARA
Duration : 2020 (January to December)
Budget(FY 2020) : LKR 0.9 Mn
Location : Pigeon Island National Park (Trincomalee) and Bar Reef Marine Sanctuary (Kalpitiya)
LocationSource of funds : NARA

Introduction

Ocean warming has an impounding impact on the coastal sensitive ecosystems, especially on the coral reefs. Heating and cooling of the ocean is mainly driven by the position of the earth in respect to the sun. Persistent raise in temperature for a longer period causes stress on the coral reefs than diurnal or shorter fluctuation.

Findings of scientific research certainly signify the changes of the atmosphere, the ocean, and the effects of anthropogenic activities. Rising ocean temperature affect coral reef ecosystems, by breaking symbiosis bond between coral reef and zoozanthelle (Bolaños*et al.*, 2020). The warming of ocean, also cause thermal stress to corals and cause bleaching and infectious diseases. As sea surface temperatures have already increased on average by 0.6 °C since preindustrial times and are projected to increase by at least another 2 °C under a business as usual scenario by the year 2100, coral bleaching events are expected to increase in frequency and intensity over the coming decades (Soares*et al.*, 2019).

Methodology

Based on the requirement, two major sites were selected as the area of study: the Bar Reef in Kalpitiya and the Pigeon Island National Park in Trincomalee. The temperature data loggers were positioned in 2018 at 5 m and 10 m depths. For this study temperature data from 5 m depth in 2018-2019 at both locations and 10 m temperature data in 2018 at Bar Reef were used. Data recording was set-up and programed to one-hour interval to the internal memory. Monthly and hourly temperature data were averaged to find out the temperature variations at coral reef areas.

Result and discussion

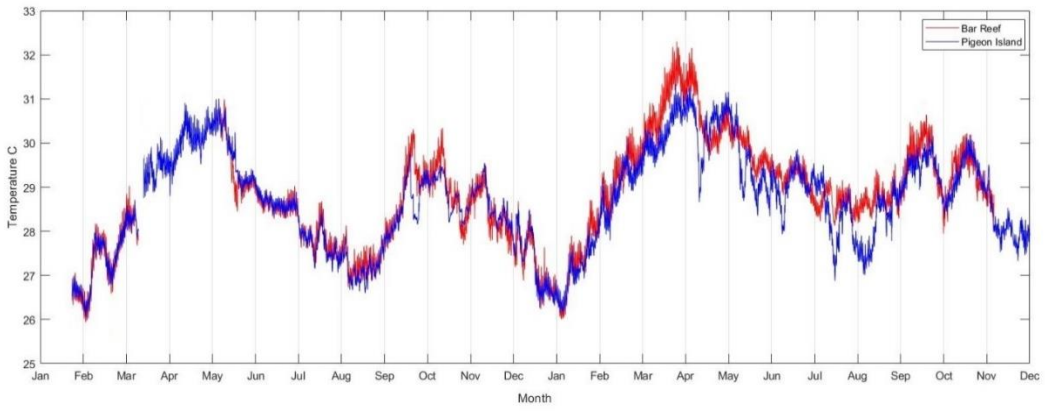


Figure 6.5.1: Monthly temperature variation in Bar Reef (red line) and Pigeon Island (blue line) from January 2018 to December 2019 at 5 m depth.

The results indicated two peaks in May and October for both years. The maximum temperature in 2018 and 2019 were 31.1˚C and 32.31˚C, recorded in May just prior to the onset of southwest monsoon. During the study period the lowest temperature was observed in end of the January prior to the northeast monsoon (Figure 6.5.1). The temperature fluctuations during the study period at Bar reef and Pigeon Island are identical except during the 1st inter monsoon when slightly higher at the Bar reef. During sampling periods temperature did not exceed critical temperature tolerance range (36˚C) for tropical coral reefs (Schoepf et al, 2015).

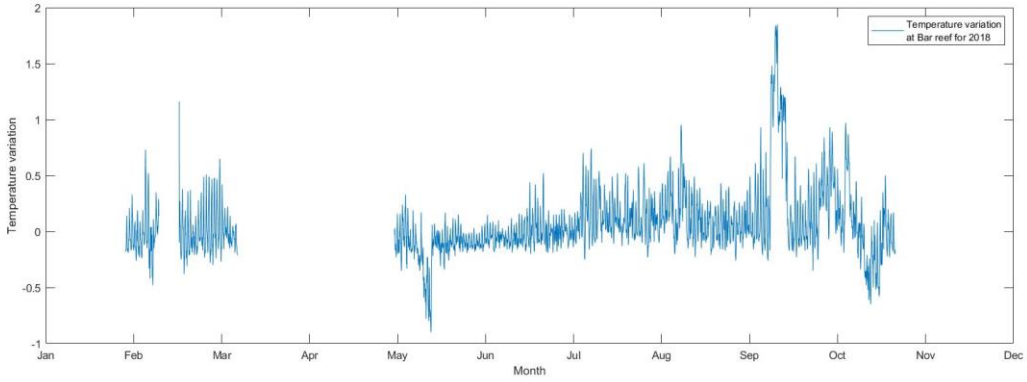


Figure 6.5.2: Temperature anomaly in 10 m and 5 m depth at Bar reef during 2018.

The observation shows that the temperature variation between the 5 and 10 m vary by ~ 0.1ºC, except for two shorter periods, extending about week, once at the mid May and the other at the beginning of October, that is just prior to the onset of southwest and northeast monsoon respectively (Figure 6.5.2). During May the lower layer (10 m) is warmer by almost 1ºC, while in October lower layer (10 m) is ~ 1.5 ºC cooler. The shorter events of stratification are critical period for sensitive coral habitats, since during this events temperature of the upper layer could easily heated up

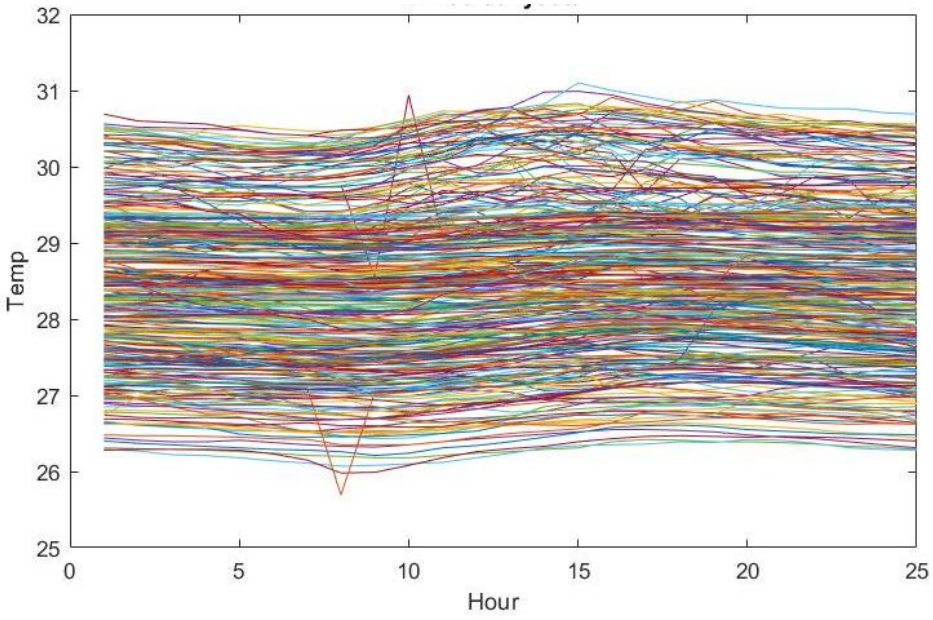


Figure 6.5.3. Daily temperature variation in Bar reef during 2019

To date 15 types of coral species were identified in the pigeon island study area. They were identified for long term monitoring for their health and growth rate study. Some of the identified species were

shown in figure 6.5.3. Amoung hard corals *Acropora* sp. show highest percentage abundance (Table 6.5.1)

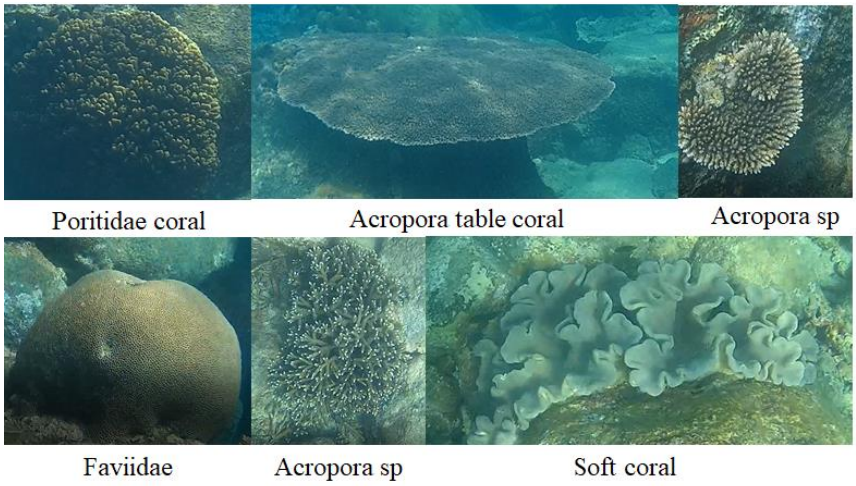


Figure 6.5.4. Identified coral species in the Pigeon Island study site

Table 6.5.1. Precentage abundance of coral species in the pigeon island study area during 2020 March

Species	Precentage
Acropora sp	15.58
Acropora sp	7.79
Acropora sp	6.49
Table coral	2.59
Brain coral	1.29
Brain coral	2.59
Soft coral species 1	31.16
soft coral species 2	15.58
soft coral species 3	6.49
Pocilloporasp	3.89
Porites sp	1.29
Millioporasp	1.29
Fungiasp	1.29
Unknown 1	1.29
Unknown 2	1.29

Conclusion

Temperature, in the shallow areas change often compared to deep waters. However, the data is not yet sufficient enough to reveal any long-term change of oceanographic parameters. Since, there is no local data records this data can be used to predict the temperature variability at 5m depth level at these two sites in the future.

Financial Allocation (Rs) :300,000.00

Financial progress (%): 98 Physical Progress (%): 80

6.6 Ocean Acidification and the Changes of the Marine Carbon System in Sri Lankan Waters.

Officers	:W.N.C. Priyadarshani, W.R.W.M.A.P. Weerakoon, and H.B.U.G.M. Wimalasiri
Division	: National Institute of Oceanography and Marine Sciences, NARA
Duration	: 2020 (January to December)
LocationSource of funds	: NARA

Introduction

Ocean acidification (OA), the reduction in oceanic pH caused by the oceans' uptake of anthropogenic CO_2 emissions, is a climate issue worldwide and it is predicted to impact entire marine ecosystems, by influencing the structure and productivity of ecosystems and the proliferation or disappearance of organisms over geologic time-scales. Since it would impact on for commercial industries, existence communities, cultural practices, and recreation, the necessity of crucial research in marine acidification status with other related oceanic processes is emphasized and by international climate mitigation discussions that rely on these marine resources. Current project aims to study the influence of coastal ocean acidity on Sri Lankan coastal water properties and some marine ecosystems together with seasonal and non-seasonal oceanic processes. Under the current project, two main activities were focused: to analyze available data around Sri Lanka, and to collect pH and other physical parameters to get seasonal variation in particular ecosystems which can be influenced by pH fluctuations around Sri Lanka.

Objectives

- To construct a time-series data set on ocean acidity around Sri Lanka
- To study the response of calcified phytoplankton (Coccolithophore and Foraminiferans) and coral reefs to OA
- To study seasonal variations of pH with regard to seasonal physical oceanic processes and other Stresses

Methodology

Study area, Field sampling, data collection and analysis

The study started in 2019 and collected data 2020 was carried out at two sensitive eco-systems; partially damaged and healthy coral reef systems at Bar Reef, Kalpitiya (6 points-one occasion) and Pigeon Island, Trincomalee (5 points-three occasions), with Trincomalee Bay and adjacent waters (12 points-two occasions) (Figure 6.6.1 and Table 6.6.1). A cruise was carried out from Trincomalee to Galle (9 locations). Here, eighty (80) water samples in total were collected in three locations and the Cruise covering North-East Monsoon and South-West monsoon to study pH variation together with nutrients and other physical and chemical properties. The initial sampling was scheduled to carry out monthly, but later altered the sampling intervals so that it could cover four monsoon seasons due to Covid-19 pandemic restrictions. Sampling and in situ data collection was done using R/V Samudrika and Small Out-motor fishing boats (Figure 6.6.2). Sampling time, parameters studied and their analysis techniques are given in Table 6.6.2.

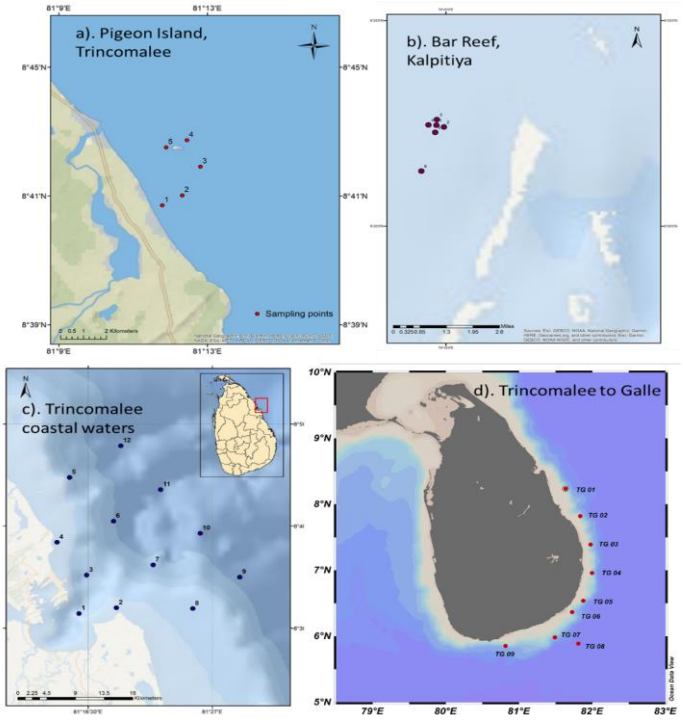


Figure 6.6.1. Sampling locations at a). Pigeon Island, b). Bar Reef and c). Trincomalee Coastal Waters and d). Trincomalee to Galle Cruise

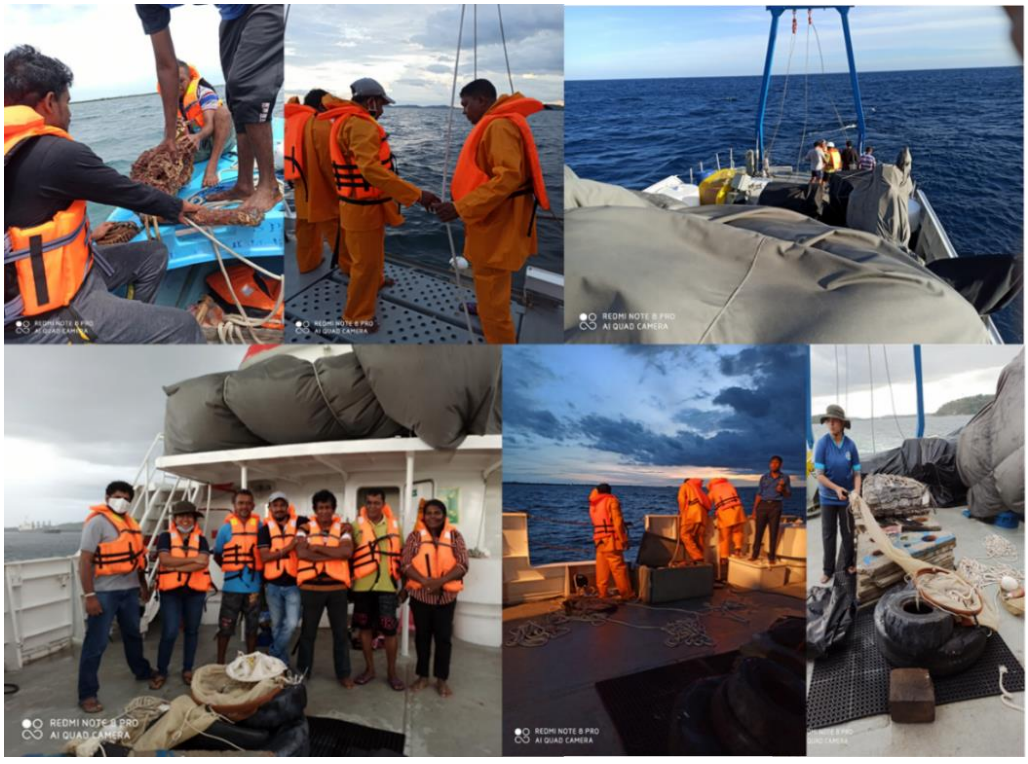


Figure 6.6.2. On board Sampling and data collection activities during year 2020

Table 6.6.1. Coordinates of Sampling locations

Station	Site	Latitude	Longitude	Station	Site	Latitude	Longitude
Trincomalee Coastal waters	T1	8.524233	81.262233	Bar Reef, Kalpitiya	BR 01	8.370300	79.746150
	T2	8.533433	81.314867		BR 02	8.376167	79.747433
	T3	8.586817	81.273117		BR 03	8.370383	79.745683
	T4	8.640333	81.231250		BR 04	8.390850	79.781850
	T5	8.746283	81.248892		BR 05	8.366433	79.743067
	T6	8.674833	81.310883		BR 06	8.325333	79.730800
	T7	8.603533	81.366700	Trincomalee to Galle	TG 01	8.236433	81.634794
	T8	8.532133	81.422500		TG 02	7.820547	81.836092
	T9	8.583550	81.488917		TG 03	7.390061	81.977739
	T10	8.654950	81.433133		TG 04	6.959444	81.997072
	T11	8.726350	81.377317		TG 05	6.538672	81.875578
	T12	8.797733	81.320983		TG 06	6.366947	81.725197
Pigeon Island, Trincomalee	PI 01	8.695790	81.198970		TG 07	5.983947	81.489203
	PI 02	8.700310	81.206850		TG 08	5.890061	81.809994
	PI 03	8.713280	81.213890		TG 09	5.853672	80.815433
	PI 04	8.725270	81.208630				
	PI 05	8.721990	81.200460				

Table 6.6.2. Sampling time, and analysis techniques used for parameter measurement

Sampling Location	Sampling time	Parameters	Analysis Technique
North-Western (Bar Reef)	January & February, 2020	pH	Potentiometric method (PH 2700 (EUTECH instruments), spectrophotometric method
Pigeon Island, Trincomalee	March, July, September, 2020	Temperature	multiparameter/
			CTD
Trincomalee Bay & Coastal Waters	July, September, 2020	Salinity	multiparameter /CTD
Trincomalee to Galle	October, 2020	DO	Winkler method/CTD
		TSS	Water sampling /Gravimetric Method
		Nutrients	Nitrate/Nitrite- Cd reduction method
			Phosphate- Ascorbic Method
			Silicate - Salicilic method
		Chlorophyll a	Water sampling
			Gravimetric method
		Plankton (Phyto & Zoo)	Water sampling
			Light Microscopic analysis

Results and discussion

Available data analysis

Here, five spatial maps and ten vertical maps of pH were produced for ten transects based on R/V Dr Fridtjof Nansen Cruise in June-July, 2018 (Figure 6.6.3 and 6.6.4).

According to the resulting maps from Nansen data, pH drops down (<8.00) is shown from Southern coastal waters (Dondra) along to North-Western surface waters (Mannar) during South-West Monsoon (Summer time) while Dondra to Eastern and Northern Coastal waters pH remained over 8.00. In normal sea water, although pH should be approximately 8.20, the pH variation in summer time is considerably lower around sri Lankan waters compared to long term acidification resolution (0.01 per 120 years). However, lower pH in surface southern coastal waters should be correlated with upwelling which brings deep waters with low pH waters to upper layers during summer monsoon mixing. In general, over 100 m depths, pH remains lower than 8.00 which is quite acidic compared to surface waters (Figure 6.6.3). During water mixing, low pH water resulted from remineralization in deep waters could come to surface and it would alter all biogeochemical cycles. According to the vertical profiles, western and southern side water pH is decreased (<8.00 over 20 m depths) compared to eastern and northern coastal waters (8.00 over 40 m depths) while when exceeding 40 km distance, surface water also become acidic. Drivers of seasonal and/or interannual variability in mixed layer which cause for the pH gradient from surface to lower, is dissolved inorganic carbon (DIC). Some references based on time- series stations' data, indicated that pH values could be varied with seasonal changes in temperature (T), dissolved inorganic carbon (DIC), and total alkalinity (TA). Thus, assessments of decadal changes of DIC and other related biogeochemical variables like oxygen and nutrients have to be made through analyses of repeat hydrographic sections across major basins and over time at few ocean time-series sites.

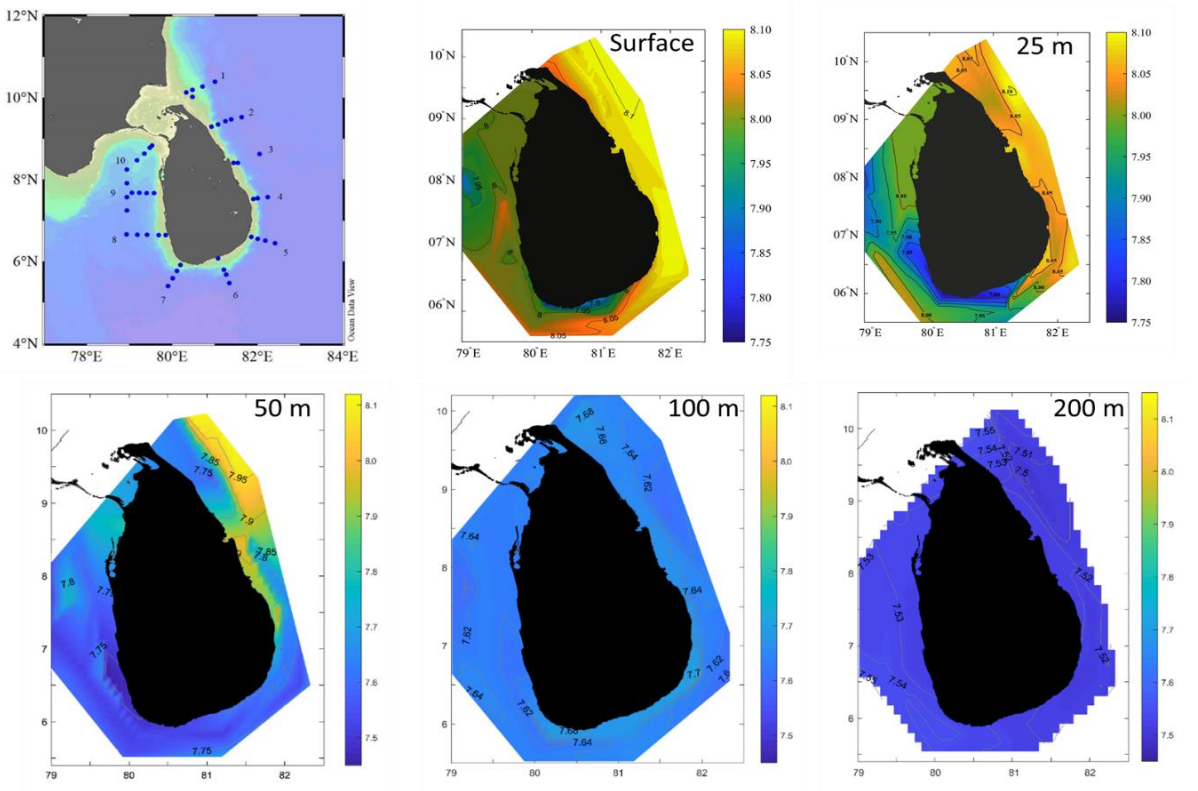


Figure 6.6.3. pH variation at the Surface, 25m, 50 m, 100m, 200m depths around Sri Lanka (Data Source: R/V Dr Fridtjof Nansen Cruise in June-July, 2018)

Field data analysis

Acidity changes

According to the current results collected from three sites, pH is varied from 8.119 to 8.401 while the lowest values were found middle of Bar reef and near Pigeon Island. The highest value was recorded near coastal waters of Pigeon Island while pH in Trincomalee canyon area remains between 8.166 to

8.182. Starting and ending area of the canyon showed low pH waters compared to other ten locations. Since,the data was collected at Bar reef and Trincomalee area during two different seasons, a clear spatial comparison cannot be done between those values. Similarly, there was no clear correlation between pH and temperature variation to confirm whether it is a driving factor or not. Continuous monitoring of pH variation together with carbonate system including total alkalinity and DIC in future work in time-series study is required to obtain solid conclusion.

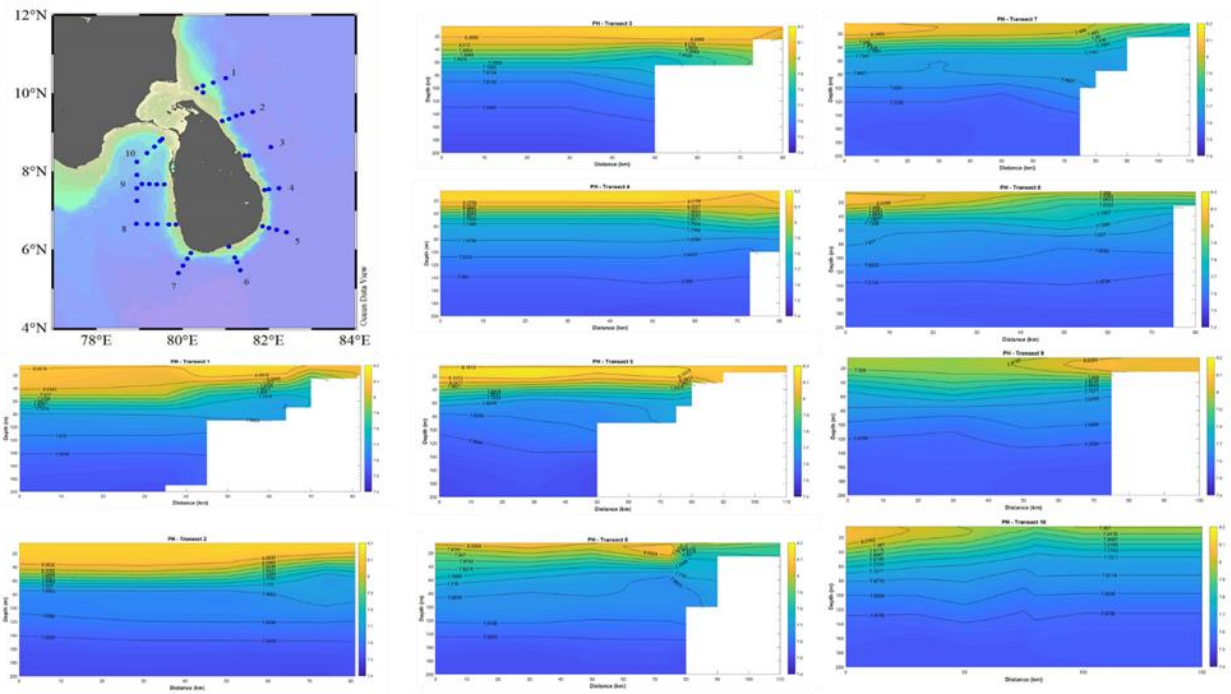


Figure 6.6.4. Vertical profiles from surface to 200m depths for ten transects were generated during June - July, 2018.

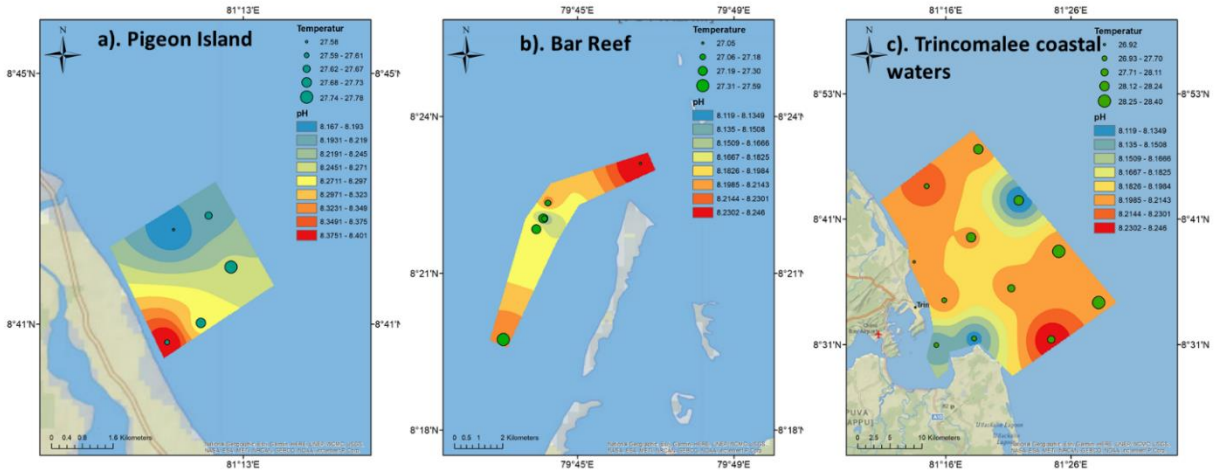


Figure 6.6.5. pH and temperature variation at Three sites; a). Pigeon Island, (March) b). Bar reef (January) and c). Trincomalee coastal waters (July) in 2020.

The spatial variation of pH based on cruise from Trincomalee to Galle during second-inter monsoon (October, 2020) shows that the acidity is quite high in eastern coastal waters (pH< 7.412) while south west coastal pH varied from 7.790 to 8.052. Only Galle area had considerably high pH (8.052 to 8.110) compared to other areas. The low pH waters in eastern areas could be resulted from deep-water mixing

during South-West monsoon (summer time) upwelling in southern coastal waters and eastern Sri Lanka Dome waters which could bring acidic waters in surface layers and transported to eastern side.

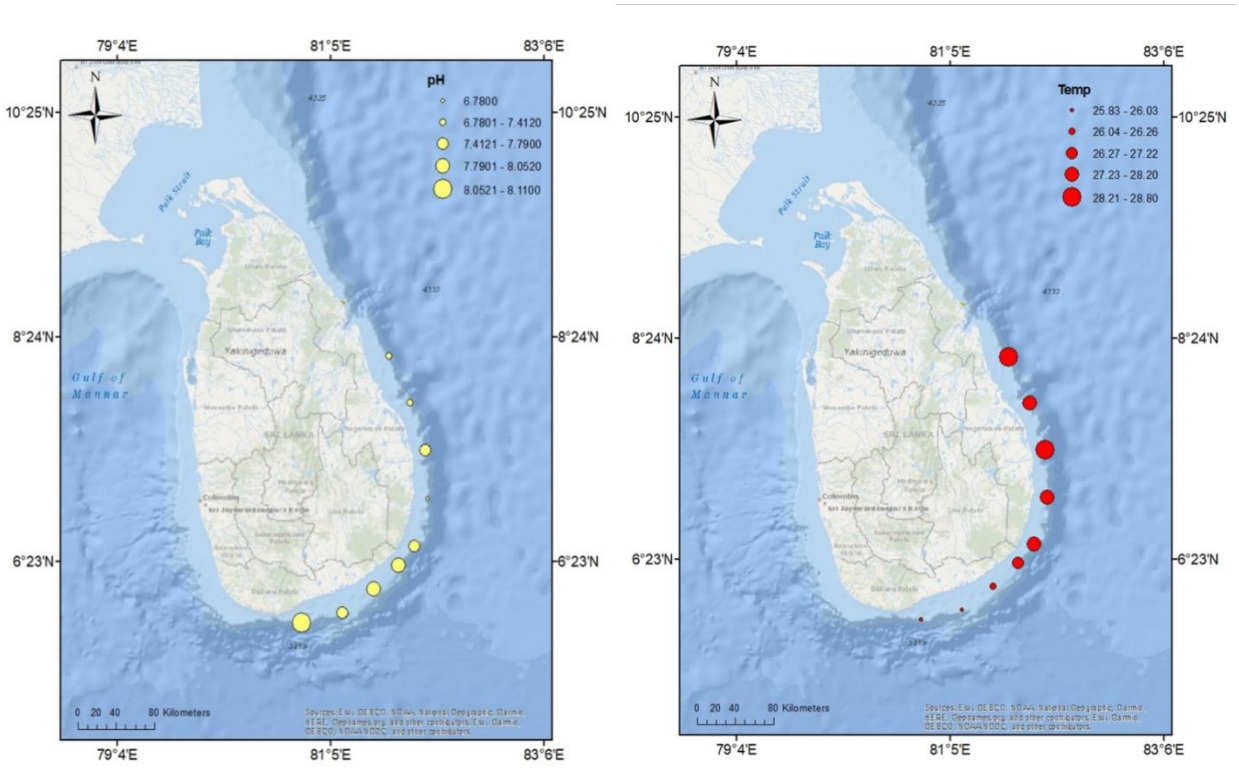


Figure 6.6.6 . pH and temperature variation from Trincomalee to Galle in October, 2020

Physico-Chemical Parameters

Salinity and Temperature

Salinity variation at Pigeon Island during 1st inter-monsoon (March) and SW monsoon (July and September) was 32.90 to 33.35 PSU while average values were 33.09 PSU, 33.33 PSU, and 33.02 PSU during March, July and September months respectively. Sanity varied from 32.90 to 33.41 at Bar reef during January and February (North-East monsoon-NE) while it was ranged from 32.80 PSU to 33.18 PSU in Trincomalee coastal waters. According to the Cruise data from Trincomalee to Galle in October, 2020 showed that coastal water temperature from eastern coast to southern Coast was not varied much (33.06 PSU to 33.98 PSU) and the average value was 33.54 PSU.

Average temperature changes in Pigeon Island area were 28.39 ^{0}C, 27.67 ^{0}C and 27.35 ^{0}C in March, July and September respectively while it was slightly low in SW monsoon season compared to 1st inter-monsoon. Average temperature changes in Bar reef area were 27.27 ^{0}C and 28.41 ^{0}C in January and February (NE monsoon) respectively. Low temperature values in January (middle of NE monsoon) could be directly related with NE monsoon wind mixing and fresh water inputs from Kala Oya discharge. Temperature in Trincomalee coastal area fluctuated between 26.92 ^{0}C to 28.40 ^{0}C in July and 26.48 ^{0}C to 28.04 ^{0}C in September while average values remained as 27.88 ^{0}C and 27.39 ^{0}C accordingly. Water temperature from Trincomalee to Galle area during October, 2020 showed gradual reduction from Eastern (28.80 ^{0}C) to Southern side (25.83 ^{0}C) which could be directly related to cold

water upwelling in summer time. However, satellite derived data also has to be considered in future analysis for better interpretation of the observations.

Nutrients

The highest average Nitrite-N (NO_2-N) and Nitrate-N(NO_3-N) in **Pigeon Island**were 0.051 µg/l and 0.086 µg/l at the end of Summer (September) while average Phosphate-P (PO_4-P) and Silicate-Si (SIO_3-Si) amounts were 0.046 µg/l and 0.066 µg/l during Summer time (July) respectively, (Table 6.6.3). All nutrients in Pigeon Island in all measured monsoon were < 0.10 µg/l.

All four nutrients (NO_3-N, NO_2-N, PO_4-P and SIO_3-Si) in **Bar reef** area were quite higher (0.025 µg/l, 0.096 µg/l, 0.024 µg/l and 0.056 µg/l) at the end of North East monsoon, (February, 2020) and quite similar to the values in Pigeon Island during South West monsoon, (Table 6.6.4).

According to the laboratory results (Table 6.6.5), the nutrient constituents (NO_3-N, NO_2-N, PO_4-P and SiO_3-Si) **in Coastal waters of Trincomalee** during South West monsoon showed that the levels were 0.062 µg/l, 0 .014 µg/l, 012 µg/l and 0.058 µg/l respectively and all parameters except NO_2-N were slightly high compared to Bar reef (Western side values in NE monsoon).

Results of the Cruise from **Trincomalee to Galle** during Second inter-monsoon (October, 2020) showed that average concentration of nutrients (NO_3-N, NO_2-N, PO_4-P and SiO_3-Si) was 0.037 µg/l, 0.009 µg/l, 0.010 µg/l and 0.026 µg/l respectively while maximum NO_3-N (0.104 µg/l) and PO_4-P (0.018 µg/l) was found in Galle area although maximum values of SiO_3-Si (0.039) was in Trincomalee area, (Table 6.6.6).

Chlorophyll- ***a***

The average Chlorophyll *a* (Chl-*a*) was also higher (> 3.892 µg/l) in Bar reef area at the end of NW monsoon than the Pigeon Island coral reef area maximum values (2.041 µg/l) recorded in first inter monsoon (March) and Summer (July), 2020 (Table 6.6.3 and Table 6.6.4). Although the average values of Chl-*a* were low in Bar Reef area, the maximum values exceeded 12.000 µg/l in some locations. At the end of September, Chl-*a* was quite reduced in Pigeon Island area compared to previous seasons.

During the Summer time (July, 2020), average Chl-*a*concentration in Trincomalee Coastal area was 5.145 µg/l while it varied from 2.433 µg/l to 9.667 µg/l in spatially. But, at the end of Summer, that average value decreased up to 1.866 µg/l together with maximum values.

With the onset of Second inter-monsoon, Chl-*a* from Trincomalee to Galle ranged from 0.898 µg/l to 9.232 µg/l while South-East area had > 4.235 µg/l of concentrations which could be related to nutrient-rich cold water upwelling due to Sri Lanka Dome phenomena during summer time.

Table 6.6.3. Nutrient, TSS and Chl-*a* concentration at Pigeon Island in March, July and September, 2020

Date	location	Site NO	Nutrients				TSS (mg/L)	Chl-a (mg/m^{-3})	DO (mg/L)	Salinity (PSU)
			NO_3-N (µg/L)	NO_2-N (µg/L)	PO_4-P (µg/L)	SiO_3-Si (µg/L)				
March, 2020	Pigeon Island	1	0.030	0.030	0.005	0.029	4.00	1.304	6.45	32.95
		2	0.024	0.024	0.003	0.036	5.60	1.130	6.38	33.07
		3	0.028	0.028	0.002	0.056	7.50	0.927	6.51	33.4
		4	0.034	0.034	0.002	0.046	3.50	1.842	6.06	33.06
		5	0.009	0.009	0.004	0.032	4.00	1.739	6.78	32.95
		Mean	0.025	0.025	0.003	0.040	4.92	1.388	6.44	33.086
July,2020		1	0.014	0.014	0.053	0.097	5.90	0.725		33.29
		2	0.010	0.010	0.037	0.048	6.80	2.754		33.35
		3	0.043	0.043	0.059	0.090	4.50	2.841		33.31
		4	0.027	0.027	0.043	0.054	9.10	2.335		33.34
		5	0.043	0.043	0.039	0.041	9.10	1.552		33.36
		Mean	0.027	0.027	0.046	0.066	7.08	2.041		33.33
Sep, 2020		1	0.097	0.097	0.011	0.061	4.00	0.203		33.03
		2	0.043	0.043	0.005	0.054	51.25	0.711		32.97
		3	0.083	0.083	0.006	0.043	8.80	0.506		32.93
		4	0.096	0.096	0.020	0.063	3.40	0.638		33.07
		5	0.110	0.110	0.001	0.057	6.10	1.289		33.11
		Mean	0.086	0.086	0.009	0.056	14.71	0.669		33.022

Table 6.6.4. Nutrient, TSS and Chl-*a* concentration at Bar Reef, Kalpitiya in January and February, 2020.

Date	Location	Site Number	Nutrients				P^H	DO	Temp. (^{0}C)	Salinity (PSU)	TSS (mg/L)	Chla (mg/m3)
			NO_2-N	NO_3-N	PO_4-N	SiO_3-N						
28.01.2020	Bar Reef, Kalpitiya	1	0.029	0.064	0.003	0.042	8.069	6.09	27.17	33.20	4.30	5.391
		2	0.021	0.038	0.004	0.068	8.111	6.29	27.18	33.29	3.70	3.306
		3	0.027	0.064	0.012	0.022	8.108	6.20	27.30	33.38	6.90	0.641
		4	0.021	0.028	0.005	0.048	8.126	6.35	27.05	33.00	9.60	5.328
		5	0.023	0.045	0.008	0.056	8.102	6.00	27.30	33.35	3.70	2.404
		6	0.014	0.045	0.003	0.058	8.111	6.10	27.59	33.28	3.70	6.986
		Mean	0.023	0.047	0.006	0.049	8.105	6.17	27.27	33.25	5.32	4.009
19.02.2020		1	0.023	0.069	0.007	0.065	8.056	6.07	28.32	32.90	15.30	12.291
		2	0.033	0.125	0.022	0.072	8.121	6.24	28.32	33.08	14.10	4.023
		3	0.027	0.181	0.051	0.024	8.11	6.22	28.42	33.41	15.90	1.030
		4	0.023	0.042	0.015	0.058	8.123	6.24	28.45	33.10	13.10	4.257
		5	0.022	0.112	0.032	0.069	8.103	6.03	28.44	32.96	12.90	0.812
		6	0.021	0.047	0.014	0.048	8.112	6.12	28.52	32.95	6.30	0.941
		Mean	0.025	0.096	0.024	0.056	8.104	6.153	28.41	33.07	12.93	3.892

Total Suspended Solids

The average Total suspended Solids (TSS) of the Pigeon Island area was increased (> 14.00 mg/l) during Summer monsoon compared to previous inter- monsoon season (4.92 mg/l) while it was > 51.00 mg/l at one occasion in Pigeon Island at the end of SW monsoon (Table 6.6.3). In Bar reef, average TSS increased from 5.32 (January) to 12.93 mg/l (February) while maximum values would not exceed more than 15.90 mg/l (Table 6.6.4).

The average TSS in Trincomalee coastal waters was considerably low during SW monsoon (< 3.92 mg/l) while it increased slightly (6.23 mg/l) at the onset of second inter monsoon. However, in some Trincomalee Bay mouth area showed > 22 mg/l of TSS during month of September, which could be resulted due to fresh water plume and Sea water mixing with wind.

Cruise data from Trincomalee to Galle was indicated that average TSS of Eastern, South-eastern and Southern coastal waters did not surpass the value > 10.00 mg/l and the average TSS was 4.94 mg/l during second inter- monsoon (Table 6.6.6).

Table 6.6.5. Nutrient, TSS and Chl-*a* concentration at Trincomalee Coastal waters, July and September, 2020

Date	Location	Site Number	Nutrients				TSS (mg/L)	Chl-*a* (mg/m^3)	P^H	Temp. (^0C)	Salinity (PSU)
			NO_2-N	PO_4-P	NO_3-N	SiO_3-Si					
27-31 July, 2020	Trincomalee Coastal waters	T1	0.020	0.010	0.051	0.059	5.20	4.492	8.139	27.54	33.14
		T2	0.024	0.012	0.14	0.11	4.70	4.726	8.129	27.49	33.12
		T3	0.024	0.011	0.077	0.112	4.20	8.565	8.210	27.42	33.17
		T4	0.037	0.015	0.198	0.232	4.20	3.116	8.205	26.92	33.35
		T5	0.018	0.010	0.084	0.073	2.80	6.985	8.226	27.70	33.17
		T6	0.004	0.008	0.03	0.019	3.40	3.769	8.200	28.18	33.06
		T7	0.007	0.020	0.021	0.053	3.50	9.667	8.206	28.02	33.04
		T8	0.014	0.009	0.035	0.023	4.10	4.940	8.246	28.11	33.24
		T9	0.005	0.011	0.022	0.045	2.70	3.638	8.210	28.36	33.11
		T10	0.006	0.021	0.032	0.018	4.20	4.244	8.210	28.40	33.09
		T11	0.008	0.015	0.024	0.018	4.60	5.159	8.119	28.24	33.04
		T12	0.006	0.013	0.027	0.014	3.30	2.433	8.206	28.22	33.05
		Mean	0.014	0.013	0.062	0.065	3.91	5.145	8.192	27.88	33.13
21-25 Sep, 2020		T1	0.027	0.007	0.085	0.043	5.19	0.306	8.066	26.48	33.07
		T2	0.029	0.011	0.104	0.103	8.57	1.160	8.082	26.55	33.18
		T3	0.026	0.013	0.112	0.092	22.78	0.867	8.024	27.28	33.05
		T4	0.025	0.012	0.093	0.037	4.30	7.624	8.070	26.63	33.17
		T5	0.018	0.016	0.066	0.047	3.80	0.102	8.038	27.85	32.89
		T6	0.013	0.012	0.028	0.035	3.90	1.451	8.042	27.92	32.87
		T7	0.017	0.010	0.073	0.101	4.70	6.379	8.068	27.56	32.82
		T8	0.015	0.007	0.041	0.028	4.60	1.566	8.187	26.89	33.20
		T9	0.011	0.011	0.029	0.038	5.20	0.305	8.086	27.60	32.97
		T10	0.010	0.016	0.025	0.029	4.10	2.232	8.030	27.84	32.79
		T11	0.011	0.003	0.036	0.042	4.70	0.203	8.171	28.04	32.81
		T12	0.013	0.015	0.043	0.035	2.90	0.203	8.028	28.02	32.90
		Mean	0.018	0.011	0.061	0.053	6.23	1.866	8.074	27.39	32.98

Table 6.6.6. Nutrient, TSS and Chl-*a* concentration at Trincomalee Coastal waters, in October, 2020

Date	Location	Site Number	Nutrients				TSS (mg/L)	Chl-*a* (mg/m^3)	P^H	Temp. (^{0}C)	Salinity (PSU)
			NO_2-N	PO_4-P	NO_3-N	SiO_3-Si					
05-09 October, 2020	Trincomalee to Galle Coastal waters	TG1	0.002	0.003	0.023	0.039	3.40	1.305	7.329	28.80	33.20
		TG2	0.011	0.007	0.013	0.046	3.50	0.955	7.412	28.20	33.43
		TG3	0.009	0.006	0.014	0.017	4.10	1.666	7.611	28.80	33.06
		TG4	0.009	0.004	0.011	0.013	7.70	0.898	6.780	27.90	33.48
		TG5	0.009	0.012	0.015	0.019	5.20	4.235	7.780	27.80	33.98
		TG6	0.010	0.006	0.015	0.017	4.60	9.232	8.052	27.22	33.75
		TG7	0.018	0.016	0.061	0.026	6.90	5.074	8.045	26.26	33.75
		TG8	0.007	0.007	0.076	0.033	3.10	7.581	7.790	26.03	33.83
		TG9	0.017	0.018	0.104	0.026	6.00	7.333	8.110	25.83	33.36
		Mean	0.010	0.009	0.037	0.026	4.94	4.253	7.657	27.43	33.54

Plankton composition and abundance

Nutrient concentrations are unevenly distributed in the oceans, influencing the abundance and composition of phytoplankton communities and it would determine by the interaction between biotic and abiotic factors. Nutrient availability varies spatially and temporally, influencing phytoplankton communities accordingly. Productivity and species composition of marine phytoplankton are also regulated by trace metals, since they are required for the biochemical functions.

6.6.4.2.3.a. Pigeon Island

During first inter-monsoon, phytoplankton abundance in Pigeon Island varied from 6383 (No/m^3) to 65924 (No/m^3) while maximum values found near to coral reef area (Table 6.6.7). There were 20 of phytoplankton species identified and 12 of them were diatoms while rest of the species were dinoflagellates. Although the abundance was lowest, over 60% of the plankton community consisted with diatoms while 90% of the phytoplankton were diatoms in location PI-2 which located little bit far to coral reef area (Table 6.6.8). Here, *Leptocylindrus sp*, and *Rhizosolenia sp were* the dominant species (>80%)in PI-2 area while *Chaetoceros sp* and dinoflagellates (*Protoperidinium sp* and *Prorocentrum sp*) showed considerable contribution to the composition in coral reef area.

At the end of SW monsoon, phytoplankton abundance in same area varied 4343 (No/m^3) to 73908 (No/m^3) while the highest abundance detected area was PI-1 located near to coast and the lowest number was observed near to PI-2 similar to 1st inter-monsoon, (Table 6.6.9). Total number of species identified was 28 and over 80% of the plankton guild was dominated by diatoms, but PI-2 area population had only 76% of diatoms (Table 6.6.10). Dominant species were *Cheatoceros sp*, *Rhizosolenia imbricata*,*Coscinodiscus stellaris* and their contribution to the plankton primary production could be changed with the density changes in the season.

Table 6.6.7. Phytoplankton abundance in Pigeon Island in 1st inter- monsoon (March, 2020)

Genus	Abundance (No/m^3)				
	PI-1	PI-2	PI-3	PI-4	PI-5
Diatom					
Bacteriastrum sp.		0	5762	5544	4021
Chaetoceros sp.		100	13966	10606	6732
Coscinodiscus sp.		0	488	1808	1683
Coscinodiscus granii		0	293	0	94
Guinardia strita		0	195	0	0
Nitzschia sp		0	0	1326	1122
Noctiluca sp		0	781	482	468
Psuedosolania sp		0	1270	2290	1309
Proboscia sp		0	684	241	468
Leptocylindrus sp		3690	8106	12293	4021
Rhizosolenia sp		1995	4102	4098	3834
Thalassionema sp		0	977	0	187
Trichodesmium		0	0	964	0
Dinoflagellate					
Ceratium furca		299	2051	2531	1683
Ceratium horridum		100	488	0	0
Ceratium fusus		0	391	844	187
Dinophysis sp		0	195	0	0
Protoperidinium sp		199	9571	20247	7668
Prorocentrum micans		0	2539	2531	2712
Prorocentrum redfeildii		0	1758	121	187
Total abundance (No/m^3)		**6383**	**53617**	**65924**	**36374**

Table 6.6.8. Phytoplankton Composition (%) in Pigeon Island 1st inter- monsoon (March, 2020)

Genus	Phytoplankton Composition (%)				
	PI-1	PI-2	PI-3	PI-4	PI-5
Diatom					
Bacteriastrum sp.		0.00	10.75	8.41	11.05
Chaetoceros sp.		1.56	26.05	16.09	18.51
Coscinodiscus sp.		0.00	0.91	2.74	4.63
Coscinodiscus granii		0.00	0.55	0.00	0.26
Guinardia strita		0.00	0.36	0.00	0.00
Nitzschia sp.		0.00	0.00	2.01	3.08
Noctiluca sp.		0.00	1.46	0.73	1.29
Psuedosolania sp.		0.00	2.37	3.47	3.60
Proboscia sp.		0.00	1.28	0.37	1.29

Leptocylindrus sp.	57.82	15.12	18.65	11.05
Rhizosolenia sp.	31.25	7.65	6.22	10.54
Thalassionema sp.	0.00	1.82	0.00	0.51
Trichodesmium	0.00	0.00	1.46	0.00
Dinoflagellate	0.00	0.00	0.00	0.00
Ceratium furca	4.69	3.83	3.84	4.63
Ceratium horridum	1.56	0.91	0.00	0.00
Ceratium fusus	0.00	0.73	1.28	0.51
Dinophysis sp.	0.00	0.36	0.00	0.00
Protoperidinium sp.	3.13	17.85	30.71	21.08
Prorocentrum micans	0.00	4.74	3.84	7.46
Prorocentrum redfeildii	0.00	3.28	0.18	0.51

Table 6.6.9. Phytoplankton abundance in Pigeon Island at the end of SW monsoon (Sep, 2020)

		Abundance (No/m^3)				
	Genus	PI-1	PI-2	PI-3	PI-4	PI-5
	Diatoms					
1	*Ceratium lineatum*	2809	0	1081	1829	3948
2	*Cheatoceros lauderi*	7564	0	2909	0	0
3	*Cheatoceros costatus*	2161	0	1164	4987	0
4	*Cheatoceros teres*	3782	237	0	6732	2286
5	*Cheatoceros costatus*	0	0	0	0	3221
6	*Chaetoceros pelagica*	540	553	2660	6483	4156
7	*Cheatoceros imbricata*	0	0	0	1995	0
8	*Cheatoceros capense*	216	0	0	0	0
9	*Cylindrotheca closterium*	0	0	0	1829	0
10	*Coscinodiscus concinnus*	3998	395	2909	2161	2182
11	*Coscinodiscus stellaris*	9292	1263	1745	4987	2078
12	*Guinardia striata*	4322	0	0	1912	0
13	*Navicula Sp.*	756	474	499	748	0
14	*Nitzchia Sp.*	2917	0	0	0	0
15	*Nitzchia sigma*	2701	0	0	1745	0
16	*Neocalyptrella robusta*	3025	0	0	0	0
17	*Pleurosigma directum*	3782	0	0	0	0
18	*Pleurosigma Sp.*	0	0	332	3906	831
19	*Rhizosolenia setigera*	3458	0	249	0	2597
20	*Rhizosolenia imbricata*	12426	395	3325	9974	8519
21	*Thalassiosira nitzschioides*	0	0	0	0	2909
22	*Thalassiosira nordenskioeldii*	3998	0	0	2909	0
	Dinoflagellates					
23	*Prorocentrum micans*	3242	0	166		2182
24	*Prorocentrum redfieldii*	0	0	0	0	2286
25	*Protoperidinium conicum*	0	0	0	0	727

26	*Protoperidinium diabolum*	1837	1026	0	2660	2597
27	*Protoperidinium redfieldii*	0	0	0	0	0
28	*Preperidimium meunieri*	1081	0	0	0	0
	Total Abundance (No/m^3)	**73908**	**4343**	**17039**	**54857**	**40519**

Table 6.6.10. Phytoplankton Composition (%) in Pigeon Island at the end of SW monsoon (Sep, 2020)

Genus	Phytoplankton Composition (%)				
	PI-1	PI-2	PI-3	PI-4	PI-5
Ceratium lineatum	3.8	0.0	6.3	3.3	9.7
Cheatoceros lauderi	10.2	0.0	17.1	0.0	0.0
Cheatoceros costatus	2.9	0.0	6.8	9.1	0.0
Cheatoceros teres	5.1	5.5	0.0	12.3	5.6
Cheatoceros costatus	0.0	0.0	0.0	0.0	7.9
Chaetoceros pelagica	0.7	12.7	15.6	11.8	10.3
Cheatoceros imbricata	0.0	0.0	0.0	3.6	0.0
Cheatoceros capense	0.3	0.0	0.0	0.0	0.0
Cylindrotheca closterium	0.0	0.0	0.0	3.3	0.0
Coscinodiscus concinnus	5.4	9.1	17.1	3.9	5.4
Coscinodiscus stellaris	12.6	29.1	10.2	9.1	5.1
Guinardia striata	5.8	0.0	0.0	3.5	0.0
Navicula sp.	1.0	10.9	2.9	1.4	0.0
Nitzchia sp.	3.9	0.0	0.0	0.0	0.0
Nitzchia sigma	3.7	0.0	0.0	3.2	0.0
Neocalyptrella robusta	4.1	0.0	0.0	0.0	0.0
Pleurosigma directum	5.1	0.0	0.0	0.0	0.0
Pleurosigma sp.	0.0	0.0	2.0	7.1	2.1
Rhizosolenia setigera	4.7	0.0	1.5	0.0	6.4
Rhizosolenia imbricata	16.8	9.1	19.5	18.2	21.0
Thalassiosira nitzschioides	0.0	0.0	0.0	0.0	7.2
Thalassiosira nordenskioeldii	5.4	0.0	0.0	5.3	0.0
Prorocentrum micans	4.4	0.0	1.0	0.0	5.4
Prorocentrum redfieldii	0.0	0.0	0.0	0.0	5.6
Protoperidinium conicum	0.0	0.0	0.0	0.0	1.8
Protoperidinium diabolum	2.5	23.6	0.0	4.8	6.4
Protoperidinium redfieldii	0.0	0.0	0.0	0.0	0.0
Preperidimium meunieri	1.5	0.0	0.0	0.0	0.0

6.6.4.2.3.b. Trincomalee Coastal Waters

Phytoplankton abundance in Trincomalee coastal areas during SW monsoon is very high and it varied from 0.72×10^5 to 29.56×10^5 (No/m^3) while the highest density was noticed at Bay area and fresh water plume mixing area (T-7) of Bay mouth, (W.N.C. Priyadarshani, W.R.W.M.A.P. Weerakoon, and H.B.U.G.M. Wimalasiri Figure6.6.7). Location T-1, T-3 and T-7 had > 18×10^5 (No/m^3) of abundance

while rest of the areas had the population of < 3.03 $\times 10^5$ (No/m^3). The total number of species found in SW season was 34 and out of that total, 26 species were diatoms (Table 6.6.11). *Chaetoceros sp* was the dominant diatom and *Protoperidiniumsp* was the dominant dinoflagellate of the plankton community. Species varied with the location and some species (*Bacteriastrum sp*) preferred open ocean water than fresh water discharge area.

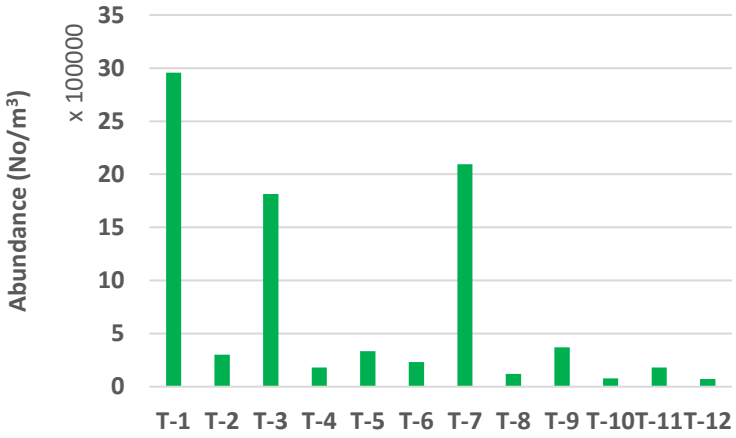


Figure 6.6.7. Phytoplankton abundance in Trincomalee coastal waters during SW monsoon (July, 2020)

6.6.4.2.3.c. Bar reef, Kalpitiya

Although sample were collected during field visits, Plankton analysis was not able to carried out due to office closure for Covid 19 pandemic and staff limitation.

Table 6.6.11. Zooplankton Composition (%) in Pigeon Island at the end of SW monsoon (Sep, 2020)

	Diatom	Phytoplankton Composition (%)											
		T-1	T-2	T-3	T-4	T-5	T-6	T-7	T-8	T-9	T-10	T-11	T-12
1	*Bacteriastrum sp.*	0.00	0.00	0.00	0.00	0.06	0.00	20.77	1.34	3.62	3.53	9.57	2.14
2	*Chaetoceros sp.*	76.25	85.03	67.75	69.39	61.66	54.63	58.24	66.82	69.44	49.47	62.73	62.10
3	*Chaetoceros costatus*	0.00	0.00	0.28	0.00	1.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	*Coscinodiscus sp.*	1.52	2.35	2.44	6.96	8.18	8.11	4.28	3.96	3.84	21.20	6.01	17.13
5	*Coscinodiscus consonance*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.21	0.00	0.00	0.00
6	*Cerataulina sp.*	1.10	1.27	1.24	1.25	2.16	2.51	1.07	1.78	1.70	0.00	0.00	1.07
7	*Eucampia sp.*	0.08	0.10	0.14	0.49	0.35	1.54	0.54	0.00	0.00	0.00	0.00	0.00
8	*Guinardia striata*	0.17	0.79	1.27	1.63	1.46	0.97	2.10	3.79	1.98	1.18	0.53	0.00
9	*Meuniera membranacea*	0.00	0.00	0.00	0.00	0.47	0.58	0.49	0.62	0.43	1.18	0.53	0.00
10	*Nitzschia sp.*	10.63	0.72	0.00	1.83	2.81	0.00	1.50	0.00	0.00	0.00	0.00	0.00
11	*Navicula sp.*	0.00	0.07	0.14	0.08	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00
12	*Neocalyptrella sp.*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.23	0.00	0.48	0.00
13	*Pleurosigma sp.*	0.08	0.19	0.00	0.68	0.23	0.00	0.00	0.80	0.30	1.18	0.00	1.28
14	*Psuedosolania sp.*	0.00	0.00	0.00	0.00	2.63	3.47	0.49	0.00	1.51	0.00	0.53	0.00
15	*Proboscia sp.*	0.00	0.00	0.00	0.00	0.18	0.97	0.39	1.29	1.77	4.71	2.66	1.07
16	*Leptocylindrus sp.*	0.42	2.91	5.50	3.04	1.17	0.97	0.54	0.00	0.00	0.00	2.13	1.07
17	*Lauderia sp.*	1.22	0.53	0.84	1.22	0.64	0.00	0.32	2.67	0.34	0.00	0.53	0.00
18	*Odontella sp.*	0.59	0.53	0.28	0.34	0.18	0.00	0.43	0.80	1.07	0.00	1.59	1.07
19	*Rhizosolenia sp.*	0.17	0.79	1.18	2.24	3.97	8.88	0.71	1.87	5.84	4.48	4.78	4.18
20	*Pseudosolenia sp.*	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.00
21	*Skeletonema sp.*	0.08	0.41	1.18	0.87	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	*Stephanopyxis sp.*	0.08	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	*Thalassionema sp.*	0.00	0.00	1.04	0.00	0.00	0.00	1.61	0.00	0.00	0.00	0.00	0.00
24	*Thalassionema sp.*	0.76	1.75	13.10	0.19	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	*Thalassiosira sp.*	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	*Trichodesmium sp.*	0.25	0.19	0.07	0.46	0.06	0.39	0.00	1.25	0.45	2.12	2.39	2.36
	Dinoflagellate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	*Ceratium furca*	0.00	0.05	0.00	0.11	0.70	0.39	0.11	0.00	0.38	2.47	0.80	1.39
28	*Ceratium horridum*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.00	0.00	0.86
29	*Ceratium fusus*	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.64	0.64
30	*Ceratium tripos*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.94	0.43	1.39
31	*Dinophysis sp.*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	1.41	0.00	1.07
32	*Protoperidinium sp.*	6.07	2.21	3.34	8.94	11.10	15.83	6.32	10.69	4.58	5.06	2.76	0.00
33	*Prorocentrum micans*	0.34	0.10	0.00	0.19	0.00	0.00	0.11	0.45	0.26	0.00	0.27	0.00
34	*Prorocentrum redfeildii*	0.00	0.00	0.00	0.08	0.23	0.58	0.00	0.00	0.38	1.06	0.64	1.18

Constraints and Future Improvements

Continuous study of the pH measurement together with other physical, chemical and biological parameters spatially in different time scales is crucial in this kind of study. But, lack of laboratory facility, instruments, chemicals and limited ship operations in bad weather conditions constrained to reach the proposed target. Hence, future improvements in sample collection, changes in sampling areas, laboratory analysis and data analysis is expected to carry out comprehensive study.

Financial Allocation (Rs) :500,000.00

Financial progress (%): 99 Physical Progress (%): 90

6.7 Sea Level Observation and Formulation of Oceanographic Data Base

Officers	: Dr. K. Arulananthan
Division	: National Institute of Oceanography and Marine Sciences, NARA
Duration	: 2020 (January to December)
Location	: Jaffna, Trincomalee, Colombo and Mirissa
Source of funds	: NARA

Justification

Sea-level is intent to increase due to the global warming. Its effect is more significant in the Indian Ocean. The observations by satellite altimeter show that the sea-level rises accelerate in the Indian Ocean since 1992, which it is much faster than the global average rising level. There were some evidences and researches indicate that Sri Lanka is one of the areas where the sea-level rise is fastest in the world.

Economic growth of the coastal areas is faster than the inland due to of the population growth and faster urbanization. The majority of coastal community is increasingly prone to ocean based hazardous such as storm surges, coastal flood, salt water intrusion and coastal erosion. To protect the social and economic development, reliable monitoring, better understanding of the process of the sea-level change, prediction of impending disasters based on science, suitable planning and adaptation are essential to device effective strategies to reduce the potential damages induced by sea-level changes.

Oceanographic data, including sea-level data is vital for the management of coastal regions. The data give insights into the dynamics of the ocean and coastal regions. Properly managed and preserved data can be used and re-used by future researchers, exploited commercially or used by educators and the general public. Such further uses will make an additional contribution to scientific advance and knowledge

Scope

Establishment of a national network of sea level stations to monitor tide, sea level and ocean-based disasters,creating dynamic data repositories that support pre-publication workflows, Creating metadata or metadata standards for discovery and assist users in finding relevant data and publications

Objectives

1. Establishing a tide and weather monitoring station on the northern coast
2. Maintenance of existing sea level stations
3. Prediction of the short-term and long-term sea-level changes
4. Establishing an oceanographic data base to be make available for research and national developments.
5. Establishing a common platform to archive, quality-controlled data and information
6. Establishing an efficient dissemination of data in required location, period and measurement intervals.
7. Products development and contribute for environmental managements

Results

Sea Level Observation Network

The study area is around Sri Lanka. It is continued by the step by step covering wholethe Island. Existing sea level monitoring network cover northern tip of the Island by Point Pedrostation,Sotherncoast cover by proposed Dondra station, west coast cover by Colombo station and east coast and east coast cover by Trincomalee station. The construction work of Point Pedro stationcompleted but not yet functional level due to travel ban and limitation of export. Trincomalee, Colombo and Mirissa stations are functioning in good condition. The Kirinda station under renovation process while Dickowita stations is proposed.

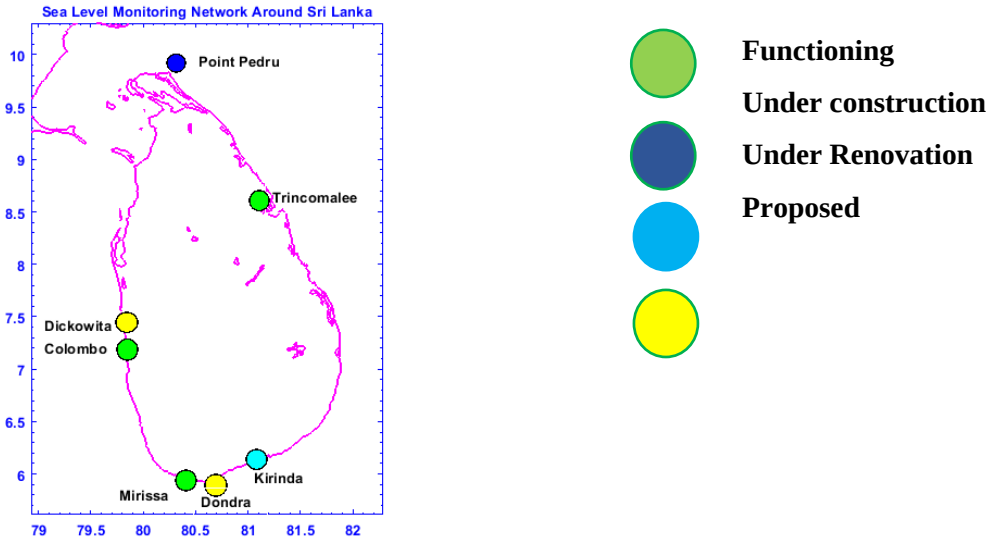


Figure 6.7.1 Major step of sea level data processed before identification of events.

Parameters and type of transmission

Sea level monitoring stations are collect and transmit mainly two category of data. They are meteorological parameters such as wind speed and direction, atmospheric pressure, atmospheric temperature, humidity, rain gauge and hydrological parameters are water temperature and sea level height. The collated data save automatically to a data logger and transmit by pre-defined time interval via satellite and General Packet Radio Service (GPRS).

Figure 6.7.2 Establishment of hydrological and metrological station at Point Pedro fisheries harbor.

Sea level and meteorological monitoring station was constructed at Point Pedro Fisheries Harbor under the permission of Ministry of fisheries and Ceylon fisheries harbor corporation (CFHC). The station is ready to install instrument relevant to meteorological and hydrological. Floor tiling is not yet complete due to modifications during installation of underwater sensors.

Table 6.7.1 Available sensors and data collecting frequency

	Parameter	**Sensor**	**Frequency**
01	Sea Level height	1. Floating tide gauge 2. Radar Sensor 3. Underwater hydrostatic pressure sensor	3m 1m 1m
02	Wind speed and direction	Wind gauge	1m
03	Atmospheric Temperature	Temperature Sensor	1m
04	Water Temperature	Underwater temperature Sensor	1m
05	Humidity	Hygrometer meter attached with temperature Sensor	1m
06	Rain fall	Rain gauge	12 hours
07	Atmospheric Pressure	Atmospheric Pressure Sensor	1m

Software and method of data processing

The software were used for data processing and analyzing Matlab, Microsoft exceland Statistical Package for the Social Sciences (SPSS). The quality controlled data are need to filtering for obtain of de tided residual sea level variation and after that can be analyzed for the events such as storm surge, meteotsunami, Tsunami. The analysis were conducted using Harmonic analyzing software and mathematical function developed by Matlab software, high frequency detection functions, moving average, analyzing of energy density spectrum and Matlab filling missing time function.

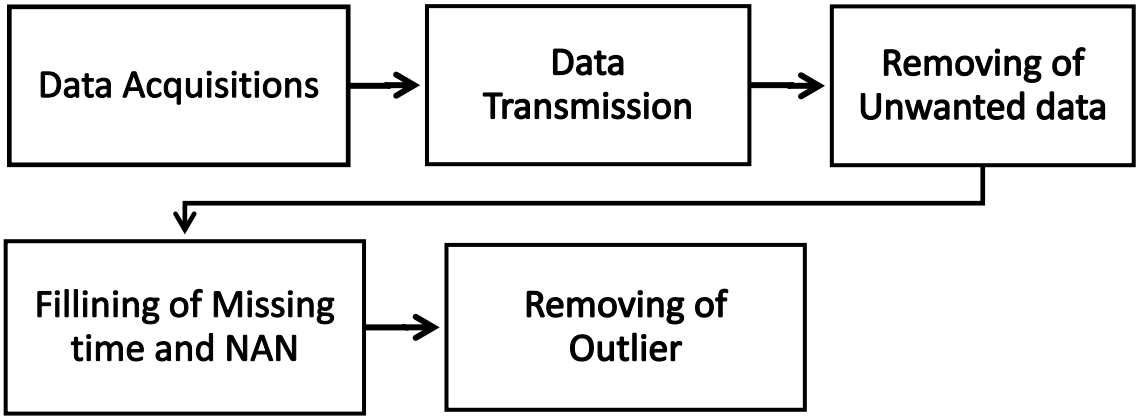


Figure 6.7.3 Major step of sea level data processed before identification of events.

The water-level time-series records were subjected to moving average filtering methods to isolate the actual hydrostatics pressure signals without effect to the original trend to the signal. The data collected from Kirinda station was included noises due to morphologicalof the location. Therefore the data was filtered using moving average each one hour time segments before used.

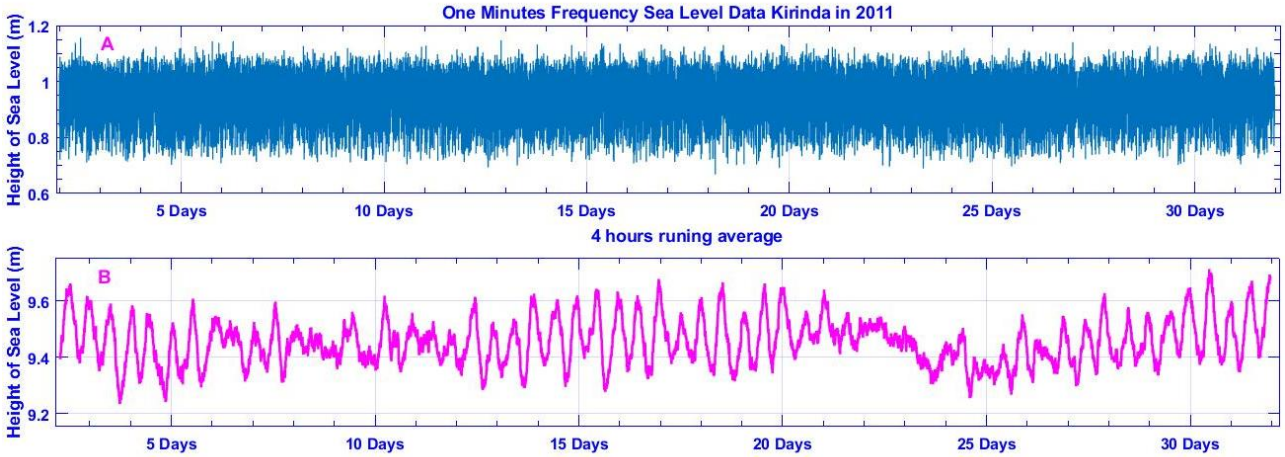


Figure 6.7.4 Filtering of noises recorded by underwater hydrostatic pressure sensor obtained from Kirinda sea level monitoring station in 2011

A. The observed water-level time series during one month of period in one minute's frequency.

B. The residual time series was subjected to moving average filtering of noises each one hours of time segments.

The shorted and filtered data were processed based on the error using different method either manually or suitable software up to a meaningful information without effecting original signals. The step of shorting, filtering and processing were done by using combination of software's Microsoft excel and Matlab feasible and required standard. The data files with missing time column and reading were corrected by the 'Time Table" function Matlab and filled missing reading with 'NAN' values. Finally the processed data was stored in .Text format in one month of time period in one minute's frequency and monthly data products were saved in .tif file and mat lab figure files format.

This table shows errors detected sea level time series during data retrieving and transmission. During the data processing identified deferent type of errors such as malfunction of sensors, reduction of sufficient battery charging capacity of the solar panels with long time prevent sunlight by dense clouds covering and accumulation of duct on the surface of the solar panel. Further barnacles attached with diaphragm of underwater hydrostatic pressure sensor stops proper functionality of the sensor recording error reading.

The processed sea level observations need to analyzed again for the meaningful information and obtaining of individual contribution of each tidal constitutes which were responsible for the temporal sea level variations. It is a complex process using large number of deferential equation and mathematical software. Therefor this process was completed Matlab function of Harmonic Analyzing of tide component.

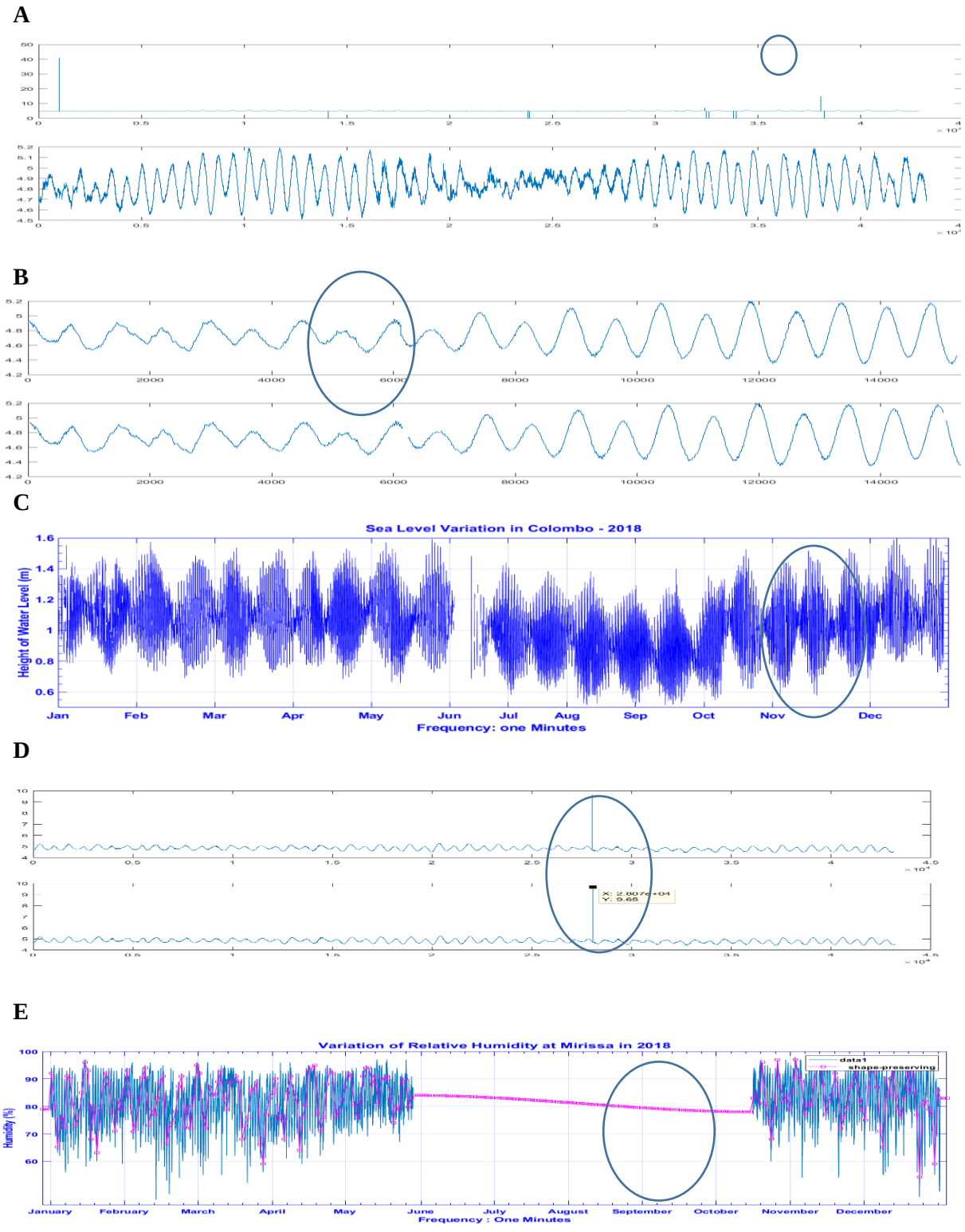


Figure 6.7.5 Errors observed during data processing

A: Data of the sensor not visualize due to positive and negative spicks data point. After removing of the spicks actualvariation was observed.

B: Pressure sensor reading with missing time fill with one minute'sand data column with "NAN" value

C: Floating tide gauge data recorded with difference datum due to malfunction of encoder.

D: Pressure sensor reading with outliers

E:Not retrieving of data due to malfunction of relative humidity sensor

The processed sea level observations need to analyzed again for the meaningful information and obtaining of individual contribution of each tidal constitutes which were responsible for the temporal sea level variations. It is a complex process using large number of deferential equation and mathematical software. Therefor this process was completed Matlab function of Harmonic Analyzing of tide component.

Prediction of the short-term and long-term sea-level changes

Sea level variation in the west coast was determined using the data of Colombo sea level monitoring station.

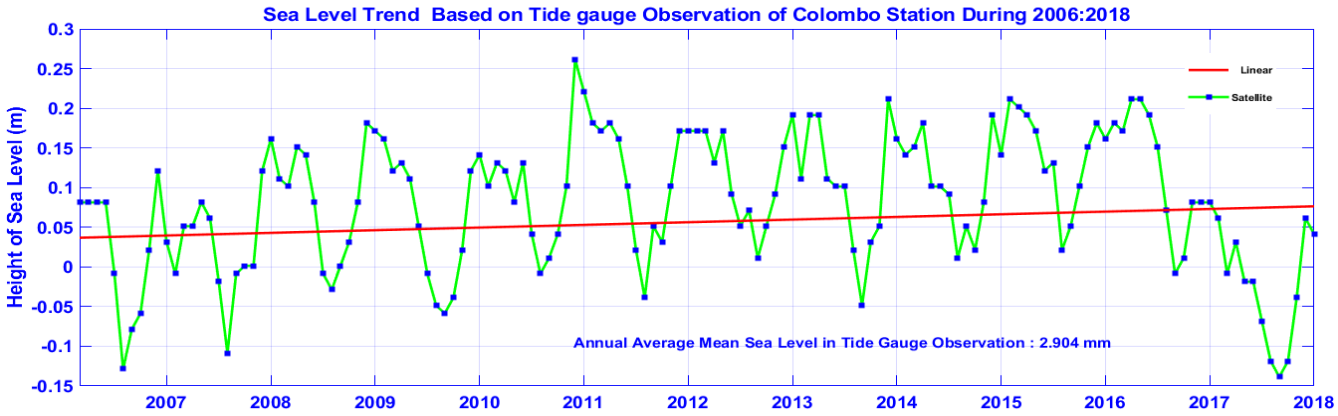


Figure 6.7.6: Long term sea level variation in the west coast of Sri Lanka

A) The red line indicated the long term trend curve generated by the mathematical software (Matlab).
B) The green line indicate the long term sea level variation according to the one month frequency.

Long term sea level variation was determined using monthly tide gauge data from the tide station stablished in the Mutual Ceylon Fisheries Harbor (CFHC) premises. The total sea level rise was observed 34.848 mm during last 12 years with 2.904 mm of annual positive sea level rise according to the available historical data. The last consecutive two years of data also was seen positive trend of sea

level variation with difference datum due to relocate of the Muthual permanent sea level monitoring station to the Colombo port authority. The sea level monitoring station was relocated due to development of Muthual Ceylon fisheries harbor to a ship yard by the Private Sector.

Comparison of Colombo Tide gauge data with satellite sea level observations.

To determination of the accuracy of tide gauge observation was compared with satellite observation in the same axis. Satellite data was obtained from Validation and Interpretation ofSatellite Oceanography (AVISO) which altimetry measurements relative to the mean ocean surface of the Earth (Geoid).

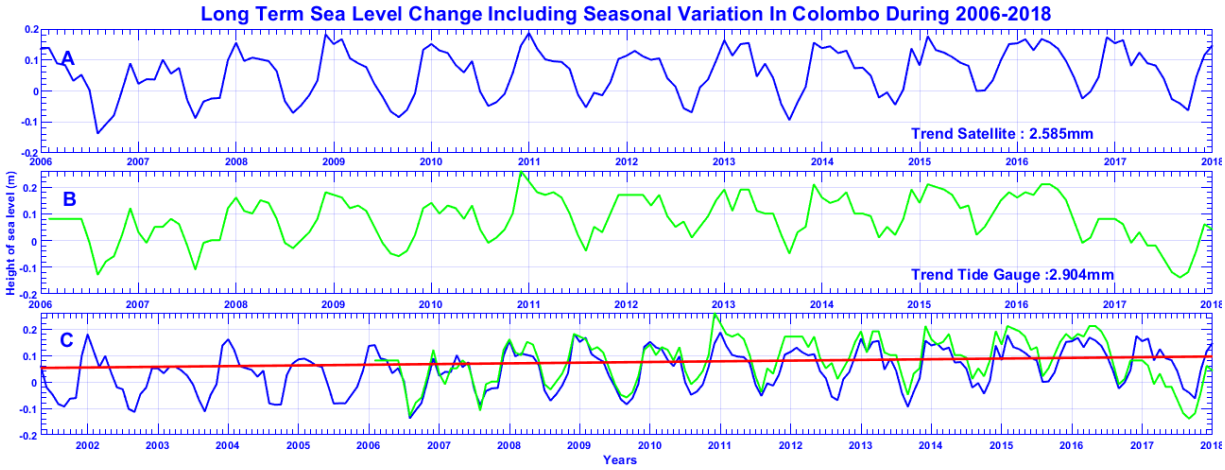


Figure 6.7.7 Long term sea level change including seasonal variation in the west coast during 2006-2018

A). Blue line is the monthly average satellite sea level variation during 2006-2018.

B). Green line is the monthly averaged tide gauge observations from 2006 - 2018

C). Comparison of the long term observations taken using deferent methods. Red line is liner fitting curve of the positive trend.

Both satellite and Colombo tide gauge observation were super positioned exhibitingthe same variation with a little difference. The satellite derived annual sea level trend is 2.585 mm while tide gauge observed annual trend 2.904 mm. The reason for the little different between both data sources of the sea level variation is satellites are used to collect gridded data giving mean value for a specific grid while tide gauge data collect in a fixed location.

Oceanographic data repository

The historical oceanographic data was organized typical hierarchical folders structure preparing the way to help access to the user. Data was arranged cruise, mooring, meteorology,sea level, sea glider in

deferent folders based on the year of the research conducted. Each folders were consisted separate folders named as row data, processed data and data products.

Further, reports and publications were saved deferent folders in each years of issued.

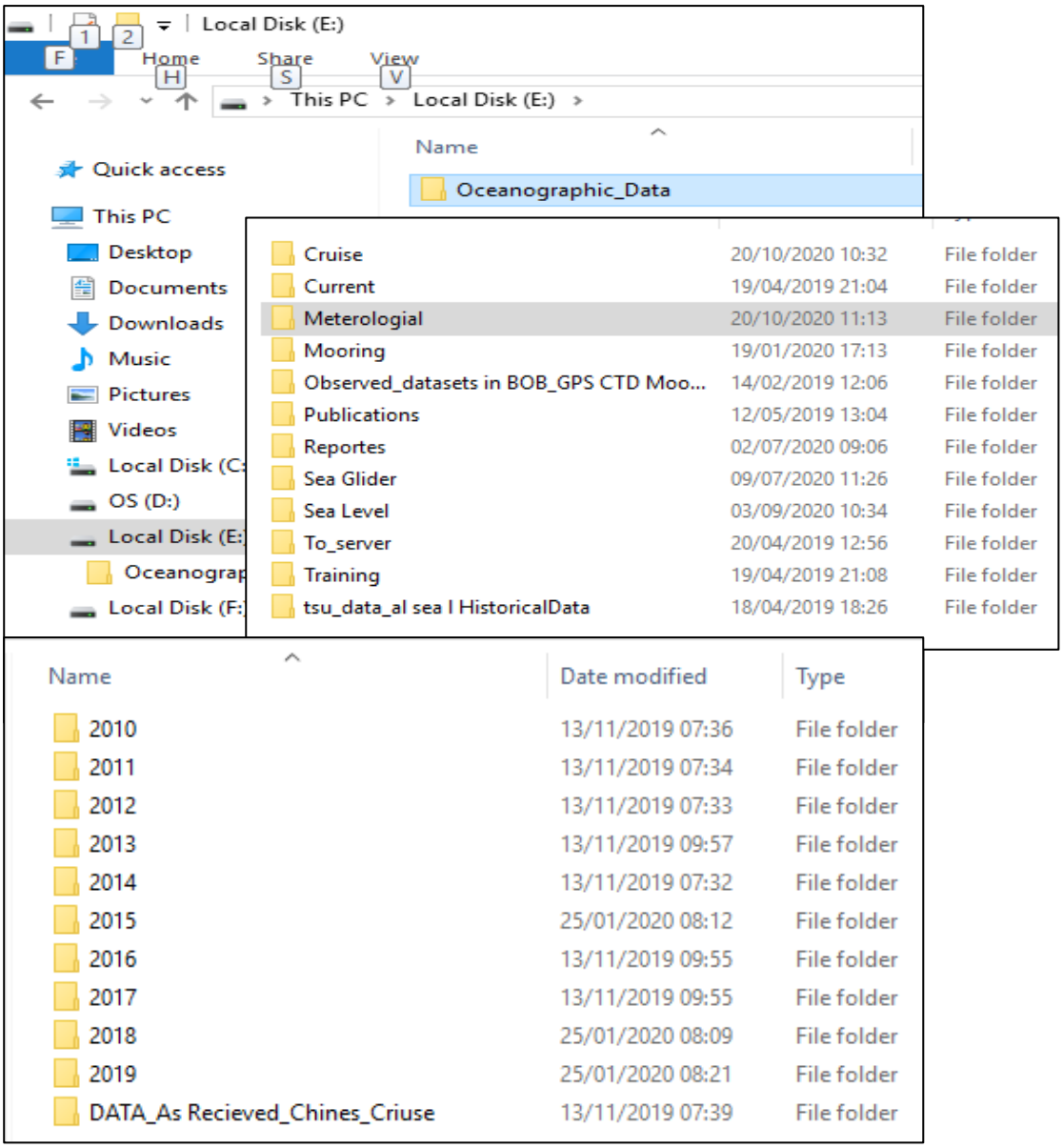


Figure 6.7.8 Hierarchical folder structure of historical oceanographic data arrange

No	Folder Name	Description
01	Sea Level Data	Data saved based on the station and data availability as monthly data files in one minute's frequency. Data was saved by the permanent sea level monitoring stations as well as temporary installed tide gauge measurements. The processed data, row data and data product saved in different folders in each years. Sea level data processing takes few steps those are removing of unwanted data column like battery voltage, program generated symbols, comma and text. After that removed negative and positive outliers/spikes, find missing time field and fill with Nan.
02	Cruises Data	Cruse data was saved in yearly basics conducted international collaborative cruises. Oceanographic data based on Physical, Chemical, and Biological Oceanographic parameters in a different folder structure.
03	Mooring Data	Mooring data was saved based on the mini mooring deployed on the surface and subsurface mooring deployed subsurface in different folder.
04	Meteorological Data	Meteorological data was saved as location of the station, year of data available and parameters in one month of data files. The meteorological data folders are Wind speed, Wind Direction, Rain fall, Atmospheric pressure, Atmospheric Temperature. The frequency of data files are change according to the data retrieved interval by the sensors. Ex: Mirissa, Kirinda, Beruwala,
05	Sea Glider	Sea glider data saved based on the glider number
06	Reports	Reports issued by the division stored under yearly folders.
07	Publications	Publications saved based on published years

Table 6.7.2: Folder structure of the National Oceanographic database

Creating of sea level database

The sea level database was created using Structured Query Language Server Management Studio 18.3.1(SQL) and Microsoft SQL server 2005. The User Interface (UI) was developed using Visual Studio. Net

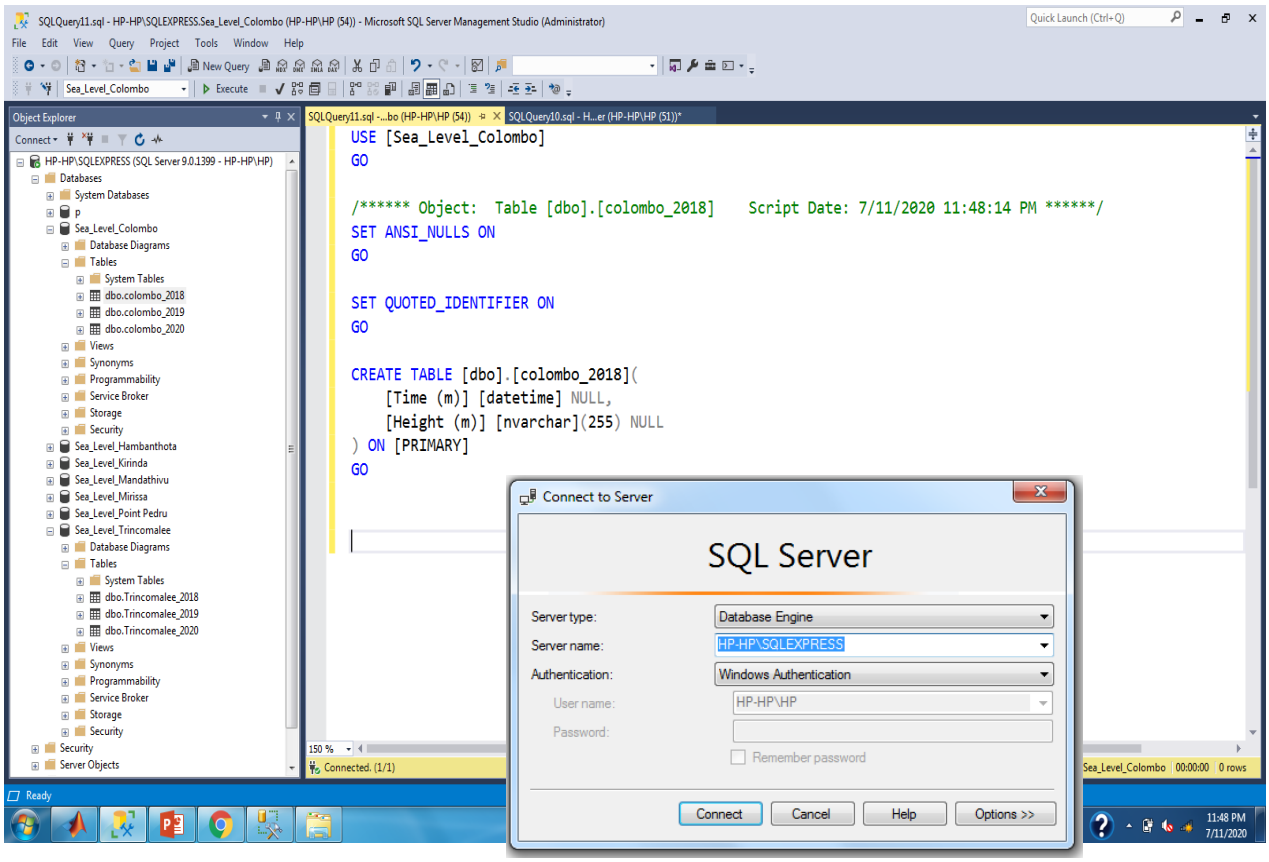
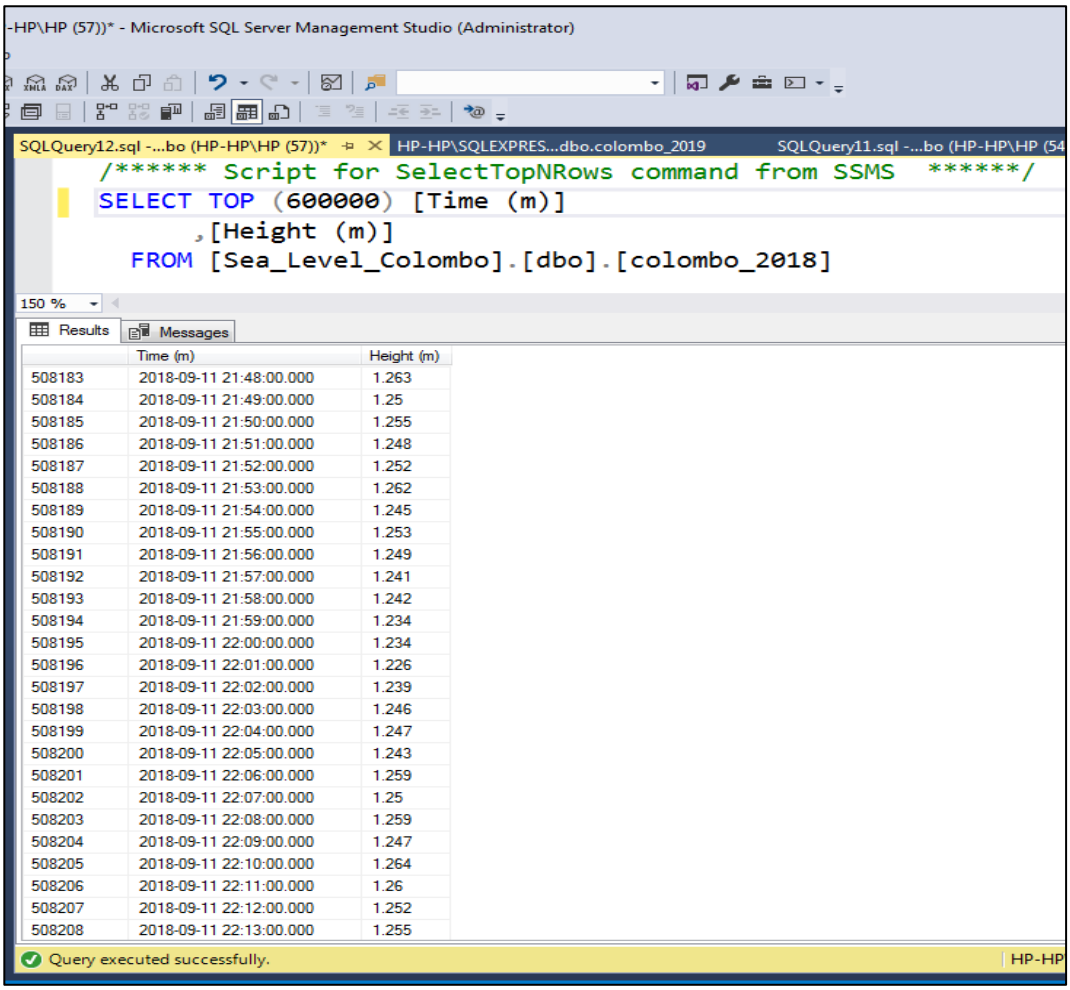


Figure 6.7.9screen shot of the sea level database

The image indicates the separate database created for each temporary and permanent sea level monitoring stations around the country as Trincomalee, Point Pedro, Mandathivu, Hambanthota, Mirissa and Trincomalee. Quality controlled data were entered under name of the station in annual files on minute's data retrieval frequency. The screen shot shows the scriptwhich used to create table with time unit in minutes and sea level height in meter allowingentering NULL values to the both columns



Figure

Displaying of entered sea level data from sea level database

The image shows screen shot of displaying Colombo 2018 sea level data file and the script for select up to 60000 of rows from the data table.

Dissemination data and data product

NARA webpage provide link to access data and data product according to the requirement of policy planers and environmental managers of coastal resource development, researchers and student. The web page consisted contact form and monthly sea level product based on availability of data in sea level stations around the country.

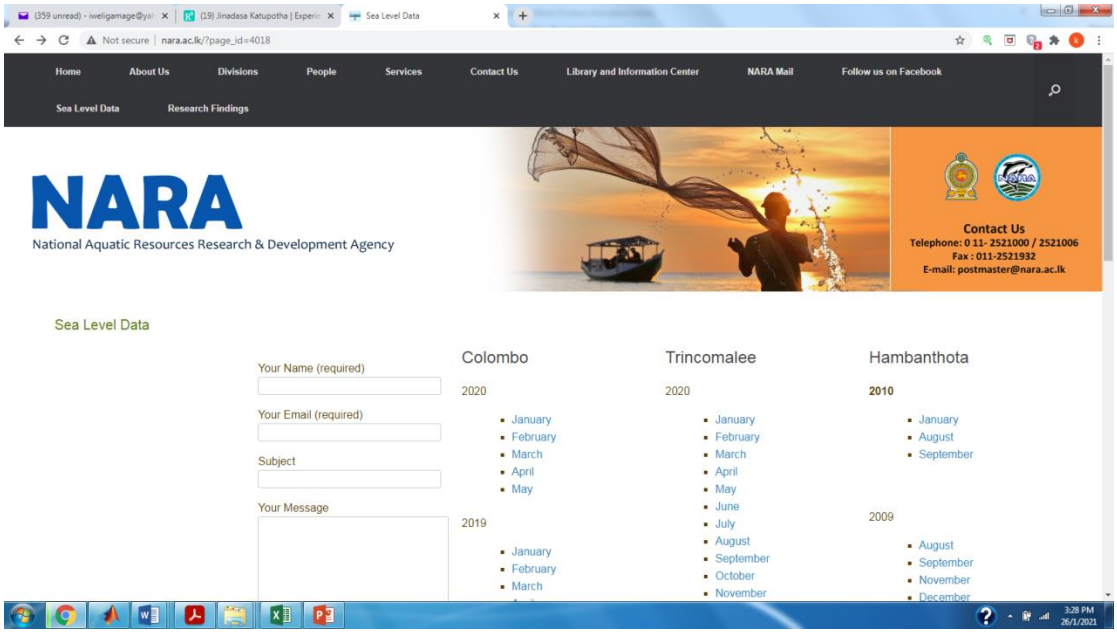


Figure 6.7.11 Sea level web page interconnected with NARA web page

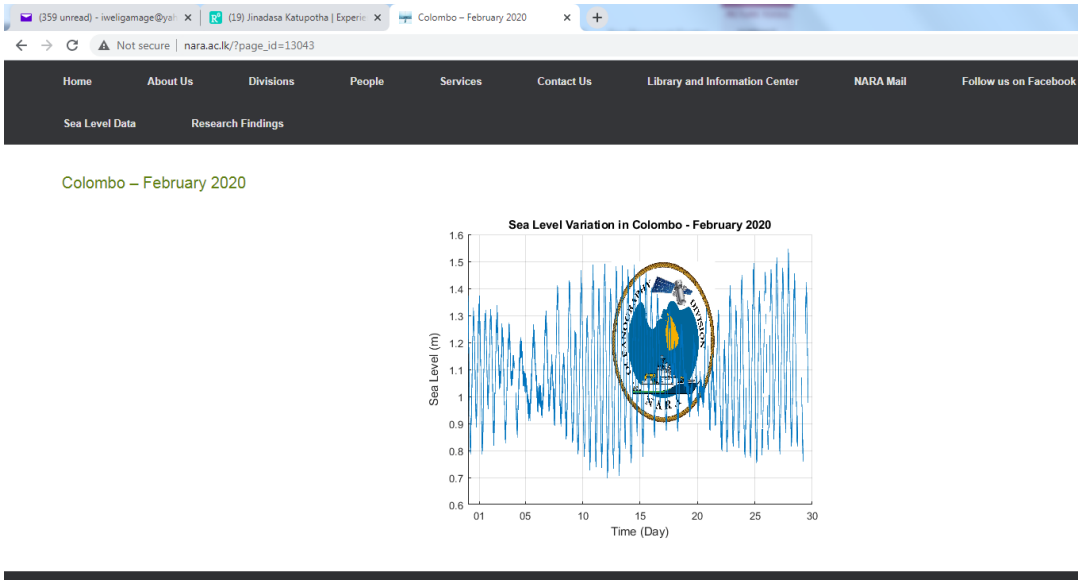


Figure Monthly sea level Product Available in the NARA web page

The contact form can be used for interested web user to send their query and request relevant to the sea level data and product. NARA hasprovided facilitate and directed approximately70 outside callerthrough contact form of the web page.Total number 583 of mails received through contact form increasing the number of users of NARA webpage, Monthly sea level data imagers were uploaded Trincomalee (2017 to 2020), Colombo (2016 to 2020) and Hambanthota (2009, 2010) stationsThe 'Sea Level Data' link of NARA web page is http://www.nara.ac.lk/?page_id=4018. The monitoring and evaluation division of the NARA contributes for the updating of sea level web link.

Table 6.7. 3: Expected output and Progress

NO	Expected out put	Progress
01	Establishing a tide and weather monitoring station on the northern coast	Completed construction of sea level station at Point Pedro fisheries harbor getting permission from the CFHC and MFARD. Now ready to install instruments.
02	Maintenance of existing sea level stations	Sea level stations at Trincomalee: Ashrof jetty, Colombo: Port authority and Mirissa: Fisheries harbor are smoothly functioning.
03	Prediction of the short-term and long-term sea-level changes	Long term Sea level variation quantified as approximately 2.9 mm per year according to the available data in the west coast of Sri Lanka
04	Establishing an oceanographic data base to be make available for research and national developments.	The historical oceanographic data was organized typical hierarchical folders structure preparing the way to help access to the user. Data was arranged cruise, mooring, meteorology, sea level, sea glider, publications and reportsissued in deferent folders based on the year of the research conducted.
05	Establishing a common platform to archive, quality-controlled data and information.	Created Sea Level database using structured Quarry Language Management Studio 18.3.1 and entered last three years of quality controlled data collected from Trincomalee and Colombo 2020: 2018. Other historical sea level data are entering in progress to the database.Historical data are available Colombo : 2006 - 2020, Trincomalee 2007-2020, Kirinda 2007-2011, Hambanthota: 2009-2010, Mirissa 2018-2019.
06	Establishing an efficient dissemination of data in required location, period and measurement intervals.	Monthly sea level data products available on the “Sea Level Data” link (http://www.nara.ac.lk/?page_id=4018)of Interconnected NARA main website. Users who access NARA web page from outside they can visualized monthly sea level graphs Trincomalee 2020 to 2017 from, Colombo 2020 to 2016 and Hambanthota 2009, 2010 stations based on data availability. Further user can sent a mail through the Contact form mentioning there queries and requirement. Already answered and directed approximately 70 questions. Received by contact form.

Discussion

Collecting of continues data is very difficult due to number of reason made by instrument and during transmission. There is no stranded method to correction of errors once, because errors are totally differ from each other's caused by reason and made in different sensors.Therefor continues maintenance is required to reduce the errors can be taken during retrieving and transmission.Purchasing of spare parts are very difficult due to not available of registered agent with relevant to manufactures in Sri Lanka.Obtain of ongoing project data for the database islarge insure from the responsible officers due to the not publish of their finding.

Making of data policy is essential for acquisition, storing, sharing within divisional, institutional and national level for the sustainable utilisation of the collected oceanic data without repeating same research wasting time and money.

Financial Allocation (Rs) :1,100,000.00

Financial progress (%): 98 Physical Progress (%): 90

Recommendations

- Policy planning and coastal resources managers need to concern on the sea level rise and related oceanic hazardous.
- The community living along the coastal belt need to well aware and Preparedness Ocean based hazardous can be taken in the future.
- Environmentalist need to concern on highly sensitive low laying coastal habitats can be effected by gradual increasing of sea level in the future withlimiting coastal land and threatening coastal life.
- Low laying agricultural coastal land need to find adaptation plan for the impact of coastal flood and salt water intrusion.
- The river mouth management plan of the country need to adaptprevent saltwater intrusion and contamination of drinking water sources with the seasonal sea level variation.

Future research

- Continuation of recording and reporting of sea level fluctuation to precise quantification of up to date positive sea level trend around the Sri Lankan waters.
- Study of destructive extreme sea level event to the coastal community such as meteotsunami, storm surge.
- Study of main causative factors and their relationship to the sea level change around the country based on long term, short term, seasonal and inter annual.
- Understanding of relationship and contribution in hydrological parameters such as salinity, temperature and current in the regional sea level variation including Arabian Sea and Bay of Bengal in the northern Indian Ocean.

6.8 Seasonal and interannual variation of Coccolithiphore sinking fluxes and their contribution to total carbon fluxes in upwelling regions of Sri Lankan waters

Officers : Dr. W.N.C. Priyadarshani

Division : National Institute of Oceanography and Marine Sciences, NARA

Duration : 2020 (January to December)

Source of funds : NARA

Introduction

Primary production is defined as the amount of atmospheric carbon fixed in particular time period or refers to the total rate of organic carbon production by autotrophs which is known as gross primary production (Bender et al., 1987).According to the global view of ocean primary production (PP) distribution (Berger et al., 1989), high PP is observed in coastal zones, Arabian sea and eastern boundary equatorial zones while low productivity occurred in central gyre regions with moderately high primary production in circumpolar regions. Recent reports based on Satellite - in situ blended observations on ocean chlorophyll a (Chl-a) indicated that > 6% of decline in global ocean annual PP since the early 1980's while 70% of that decadal reduction occurred in the high latitudes (Gregg et al., 2003). The decline of PP is suggested due to enhanced sea surface temperature (SST) by 0.2 0C and decrease in atmospheric iron deposition in northern high latitudes while amplified wind stress is in Antarctic regions.

Primary production in the ocean is contributed by plants (sea grass and sea weed) and microscopic phytoplankton (Plus et al., 2015). Fifty percent of ocean productivity is coming from marine phytoplankton. Diatoms, Coccolithophore, Phaeocystis spp., nitrogen fixing Cyanobacteria and Pico-cyanobacteria are the main players in carbon biochemical cycles with (Boyd et al., 2010) while 40% of oceanic primary productivity is from diatoms (Sartou et al., 2005). First four algal groups are bloom formers while latter group stands with influence of seasonal gradient, climate variability and changes in ocean status (Arrigo et al., 1999; Balch et al., 2005; Westberry and Siegel., 2006). Bloom formation of those groups are key vectors of exporting POC to deep ocean since their aggregation accelerates the fast-sinking of materials. The inbuilt silica shells in diatoms (Treguer et al., 1995, Lampitt, 1985) and $CaCO_3$ scales in coccolithophore acts as fast-sinking mineral ballast. Thus, any changes in plankton community structure could affect CO2 cycling and storage ultimately.

Hence, Coccolithophorids are one of the key players in the marine biological pump and marine carbon cycle, as their production and community-structure are crucial for export and sequestration of carbon from the atmosphere to the deep sea with important implications to climatic trends. Variations in the species composition of coccolithophore communities largely reflect environmental changes and are therefore fundamental for palaeoceanographic reconstructions, (Priyadarshani et al, 2019)

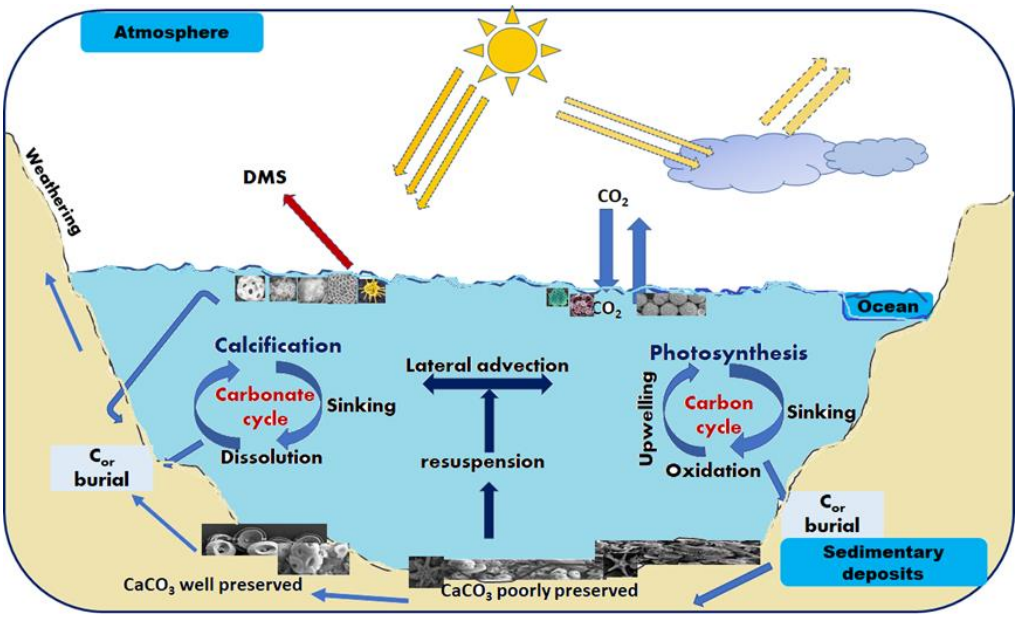


Figure 6.8.1.The complex role of Coccolithophore within carbon cycle. (modified from Petit et al., 1999 and Boeckel, 2002)

Sri Lanka, as an island located in the north of Indian Ocean and sandwiched between Bay of Bengal and Arabian sea, the marine environment around Sri Lanka and also climate on land is strongly influenced by the Indian Monsoon system, with remarkable seasonal variations. Due to the global environmental change and increasing human activities, Sri Lanka is also threatened by sea-level rise, increased frequency and strength of cyclone, marine eutrophication, hypoxia and ocean acidification, and other ecological disasters which further result in a series of social, economic and people's livelihood problems. Thus, Sri Lankan waters are an ideal area to study the response of coccolithophores to environmental change because of the remarkable seasonal and interannual variations of the monsoonal climate and the hydrography. However, to date any paleo-oceanographic / paleo-climatic studies have not been carried out based on temporal changes of coccolithophores in sri Lankan waters.

Thus, to study the time series information on changes of Coccolithophore in different water masses such as upwelling regions, coral reef area and construction/ development program on going area is very important and to understand the response of marine environment and ecological systems along the Sri Lankan watersfor the effect of global climate change and human activities and identify the vulnerable regions for climate change.

Scope

Establishsediment trap mooring system to collect sinking particles in three locations; Galle, Trincomalee and Bar reef so as to collect year around sediment particles and establish time-series data collection for Coccolithophore together with other physical, chemical and biological parameters dynamics so as to address global climate change issues.

Objectives

- To study seasonal variability of coccolithophore abundance and diversity and identify the possible environmental drivers for the seasonality.
- To correlate coccolithophorecontribution to particle flux to address succession of coccolithophore in Sri Lankan marine environment.
- To analyze the community structure of coccolithophore based on relative abundance together with ecological/environmental preferences.

Methodology

To establish time-series sediment traps in coral reef and upwelling area

Three sediment trap moorings with three sediment traps at 1000m, 2000m and 3000m were proposed to installed at southern upwelling region, Sri Lanka Dome area and Off Bar reef area to collect sinking particles for analyzing, coccoliths, diatoms, foraminifera's and silicates, opal and other organic particles. The sediment traps were proposed to give by Second Institute of Oceanography, (SIO), China under Joint Collaboration. However, the equipment was not received due to Covid -19 pandemic issues and cargo restrictions and unable to establish the time-series sediment traps.

But, 1m sediment trap was made locally to installed in Pigeon Island area to collect particles, but it also not installed in pigeon Island due to field work restrictions due to office closure for Corona pandemic safety issues.

Coccolithophore Sample collection and analysis

Water samples (10 L) from 5 sites at Pigeon Island in March, 2020 were filtered for Coccolithophore collection and the filter (nitrophore) paper preserved in freezer immediately so as to make the slides for microscopic observation at laboratory. However, slide preparation was not done since optical glue was not purchased during Corona Pandemic. Thus, Coccolithophore identification was hindered and it was abortive to study seasonal variability of coccolithophore abundance and diversity and identify the possible environmental drivers for the seasonality.

Retrieving remote sensing data

Although sampling was restricted, Remote sensing data on Chl-*a*,Mixed layer depth (MLD), and Sea

Parameter	Resolution	Source
8-day averaged Chlorophyll- a	$2^0 \times 2^0$	Aqua MODIS
Daily SST	$0.25^0 \times 0.25^0$	AMSR-AVHRR
Monthly averaged MLD	$1^0 \times 1^0$	ARGO

Surface Temperature (SST) wasretried for 6 months (January – June 2020). The data retrieving sources are indicated below.

Results and Discussion

Coccolithophore identification and lab analysis

Coccolithophore study and suspending particles were not carried out due to Corona pandemic which restricted on field activities and purchasing of some lab consumables.

Remote sensed data

Some of the monthly climatological maps for Chlorophyll a (SeaWIF) and Sea surface temperature-SST (AMSR-2) from satellite products during January to May around Sri Lanka are shown in Figure 6.8.2 and Figure 6.8.3. Mixed layer depth (MLD) variation maps taken fromArgo floats are shown in Figure 6.8.4. Those maps are being using to identify seasonal variations and relevant data will be used to reconstruct high resolution maps in future interpretation.

Chlorophyll – a

According to Figure 6.8.2, Chl-*a* concentration was > 1.60 mg/m^3 in northern and north western coastal region during North west monsoon (Jan, and Feb) while it was extended up to western coastal waters

in First inter -monsoon (March) where could be resulted high primary production areas. With the onset of South-West monsoon, high primary production was occurred in southern upwelling area and northern side coastal waters while western and eastern water showed less Chl-*a* concentrations (0.10mg/m^3-1.00 mg/m^3).

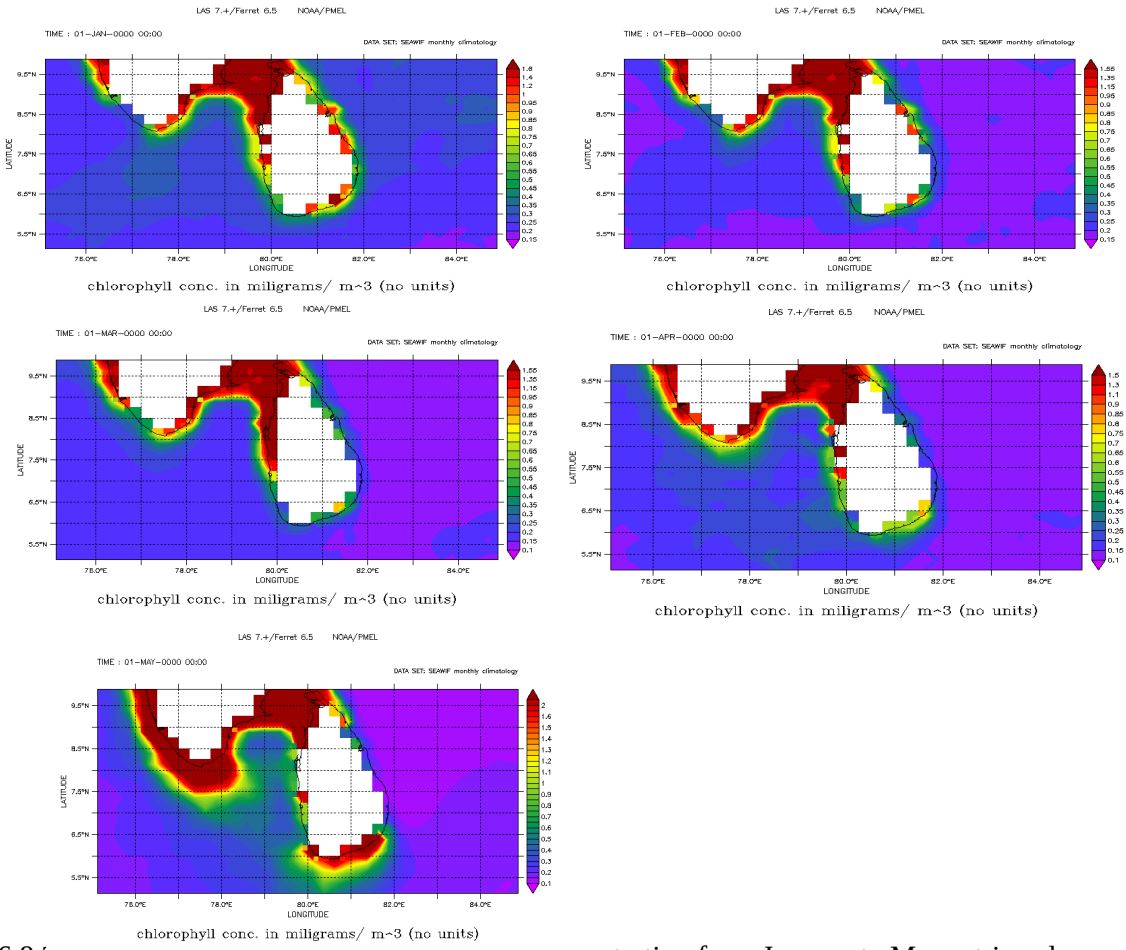


Figure 6.8.2. Monthly Climatological Chlorophyll a concentration from January to May retrieved from satellite borne SeaWIF sensors.

Sea Surface Temperature (SST)

Remotely sensedSST data around Sri Lanka during January to June varied from 27.8 to 32.25 ^{0}C. During January, SST ranged 28.4 ^{0}C to 29.6 ^{0}C and the warm water was noticed in Southern coastal waters. At the end of North East monsoon, (mid of February) SST varied 27.8 ^{0}C to 29.9 ^{0}C, while the highest values were detected in south west region. In first Inter- monsoon (March), temperature in western area was increased further due to Arabian Mini Warm Pool which a part of the Indian Ocean Warm Pool and formed in the eastern Arabian Sea prior to the onset of the summer monsoon season. This warm pool attained its maximum intensity during the pre-monsoon season and dissipated with the commencement of summer monsoon (Neema et al, 2012).

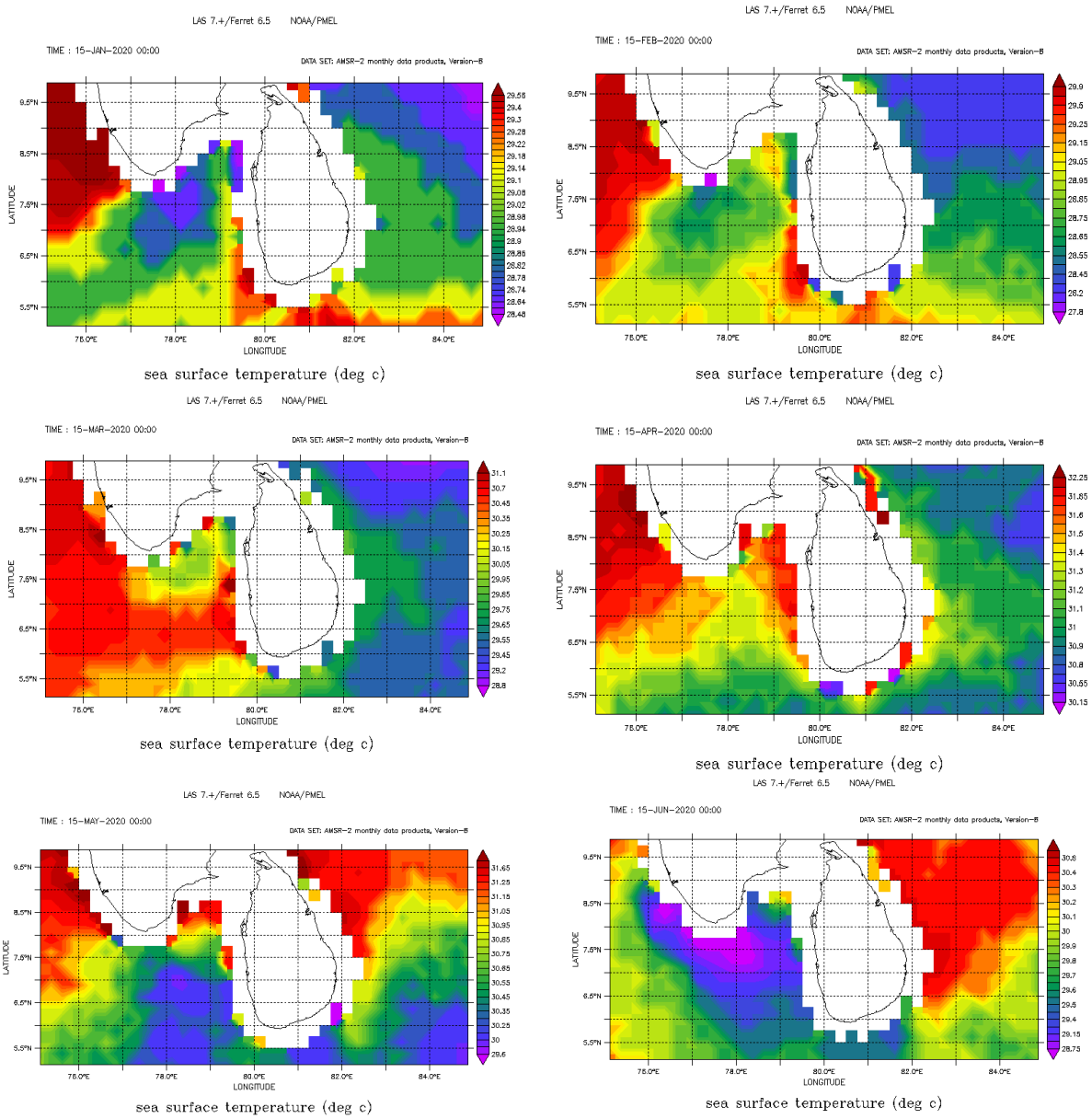


Figure 6.8.3. Monthly climatological maps for sea surface temperature (AMSR-2) from satellite products during January to May, 2020

In April, SST around Sri Lanka is much higher and it was ranged between 30.15-32.25 ^{0}C while warm water transported towards north western area from western side. With the onset of SW monsoon (May), SST rage reduced slightly (29.6-31.6 ^{0}C) and warmest water was found in NW area. Then mid of SW (June), SST variation reduced further and over 30.00 ^{0}C of SST found in NE and Eastern coastal waters while southern area was observed > 29.5 waters.

Mixed Layer Depth

During NE monsoon (January and February), MLD was > 38m around Sri Lanka waters and the maximum value found in northern and eastern areas due to proper wind mixing of the area. Shallow MLD was noticed in western and southern coastal areas. During first inter monsoon (March), MLD reduced and it ranged 21m-26m and low values found in western and southern region which related to stratification coupled with high temperatures in that area. However, the maximum values still occurred in northern and eastern waters.in April, MLD was further declined while shallow MLD (<18 m) waters found in northern coastal waters.

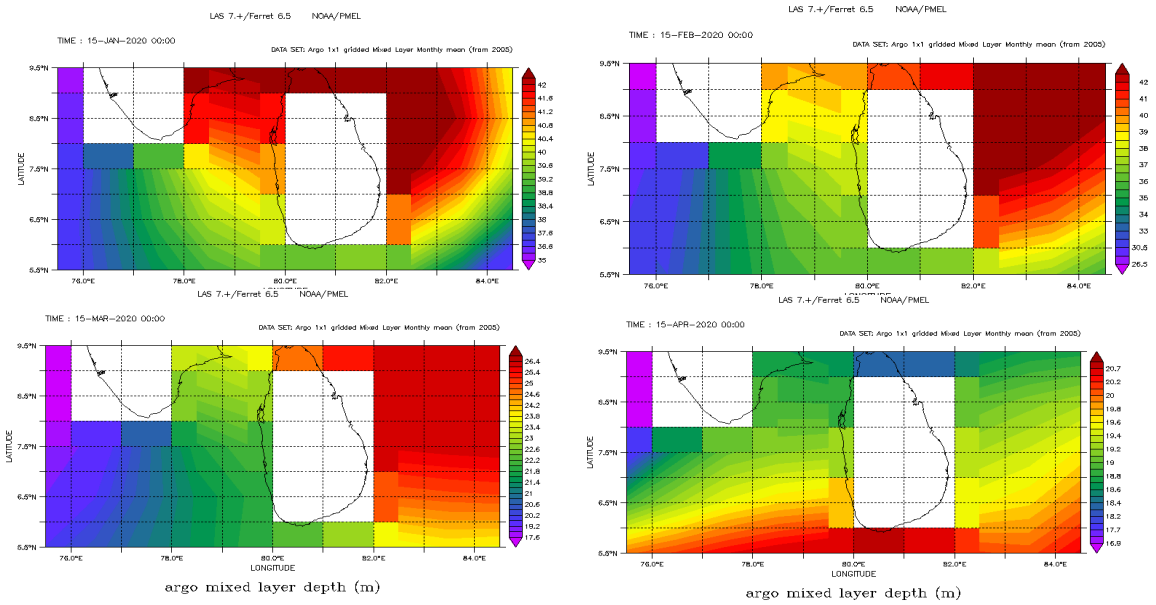


Figure 6.8.4. Mixed layer depth (MLD) variation maps taken from Argo floats during January to April, 2020

However, in general high Chla was not directly coupled with high MLD and Low SST in northern and eastern waters during NE monsoon and inter monsoon seasons. But local nutrient availability could dominate the plankton population together with high primary production in NW region.

Conclusion

Without establishing sediment traps, Coccolithophore studies were not carried out and hence, particle fluxes were not calculated. Although, an idea about primary production could be obtained through remote sensing data, on site analysis of time series samples on all particles with plankton including diatoms and coccolithophore is equally important, but unable to proceed with global covid pandemic issues. However, to establish sediment traps in critical areas will be proposed in future years.

Financial Allocation (Rs) :280,000.00

Financial progress (%): 96 Physical Progress (%): 50

7 National Hydrographic Office

7.1 National Charting Program

Project 1.1: Data Acquisition for Coastal Chart “Trincomalee to Kudremalai Point”

NHO has planned to produce a coastal chart from Trincomalee to Kudremalai Point (Scale-1:300,000) covering about 550 km coastal stretch from East to West of Sri Lanka. Total sea area covering from this chart is about 30,000 km^2.Necessary surveys were planned in two phases. 40% of the total area was already covered and could not continue Offshore surveys (beyond 200m contour) due to unavailability of RV”Samuddrika”. Anyhow northern island area was surveyed using small boat and fair sheet of the Northern Islands was completed.

Due to the COVID-19 pandemic situation, the surveys couldn’t carry out as planned within the year. Further, the surveys could not conduct due to permission delay from the Ministry of Defence (MoD) and unavailability of RV”Samuddrika”at the beginning of the year. The total distance of the surveyed lines are 2136 km in 2020.

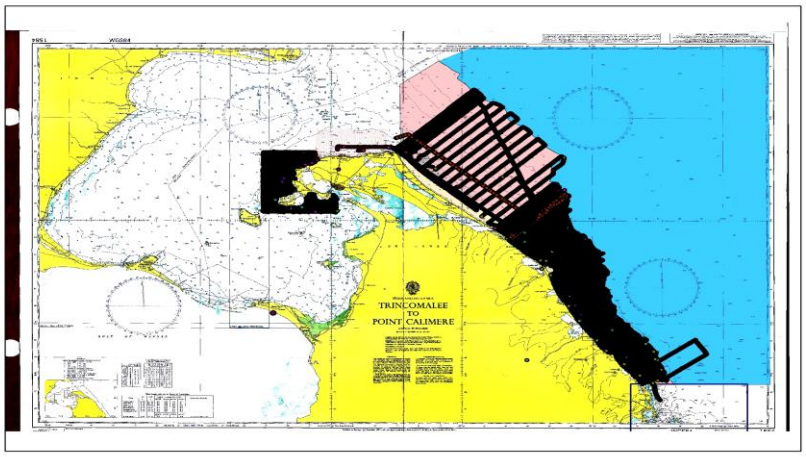


Figure 7.1-1 Bathymetry coverage for the Coastal Chart “Trincomalee to Kudremalai Point”

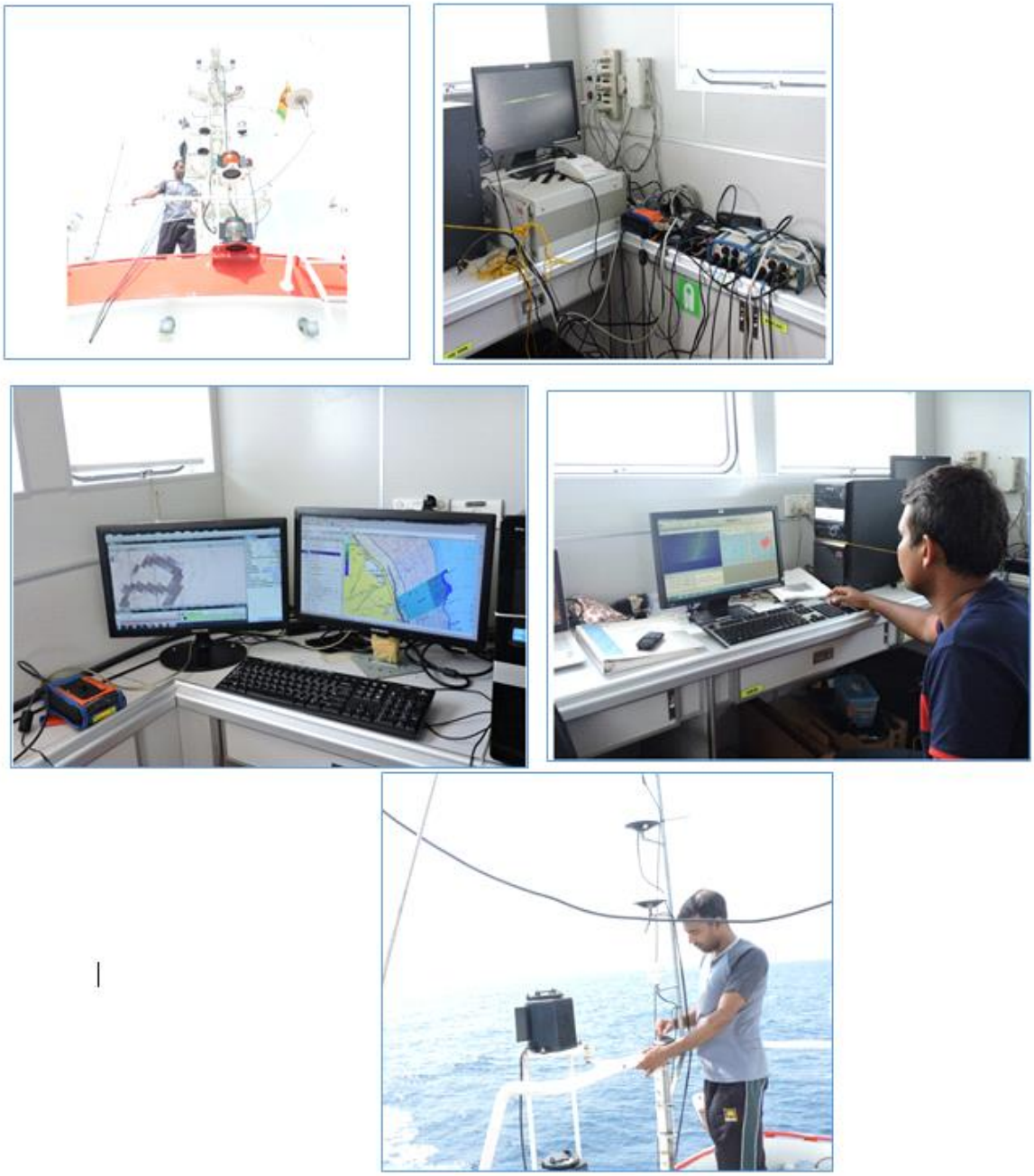


Figure 7.1-2 Field works for Coastal chart Trincomalee to Kudremalai Point

During the year 2020 NHO has planned to complete the 98% of the Nautical Chart for Mannar Island as a separate chart. Surveys for Nautical Chart “Mannar Island” could not start due to permission issue from the Sri Lanka Navy in 2020. Due to the COVID-19 pandemic situation, the surveys couldn’t carry out as planned within this year. During this year, the total distance of surveyed lines of the planned area is 509 km and it’s 5% of the total area of the nautical chart of Mannar Island.

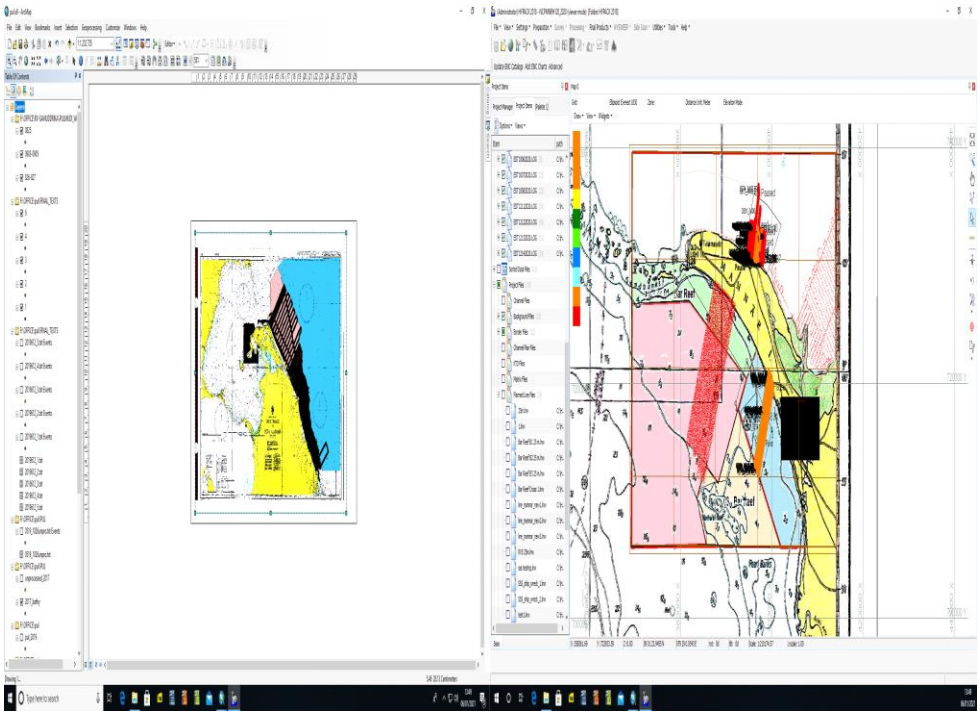


Figure 7.1-3 Bathymetry coverage for the Nautical Chart of Mannar Isalnd

Figure 7.1-4 Field works for Nautical chart of Mannar Island

Project 1.2: Data Acquisition for Coastal Chart “Little Basses Reef to Pulmoddai Roads”.

According to the National Nautical Chart Index, the total coastal belt of Sri Lanka intended to cover with five small scale charts. Nautical Chart “Little Basses Reef to Pulmoddai Roads” is one of those. This covers 250 km long coastal stretch from South to East of the island. The total area intended to survey in two phases. During the phase one NHO has planned to complete surveys up to 200m isobath using RV”Samuddrika”. Due to unavailability of RV “Samuddirka”, the data collection couldn’t completed as planned. And also the COVID-19 pandemic situation of the country is also affected for continuing the surveys as planned within this year.

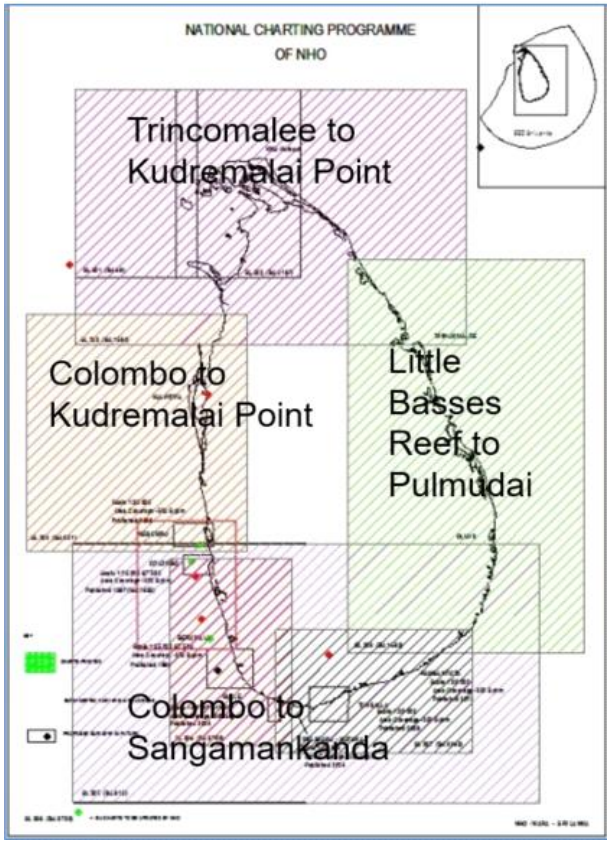


Figure 7.1-5 Nautical Charts covering the entire coastal belt

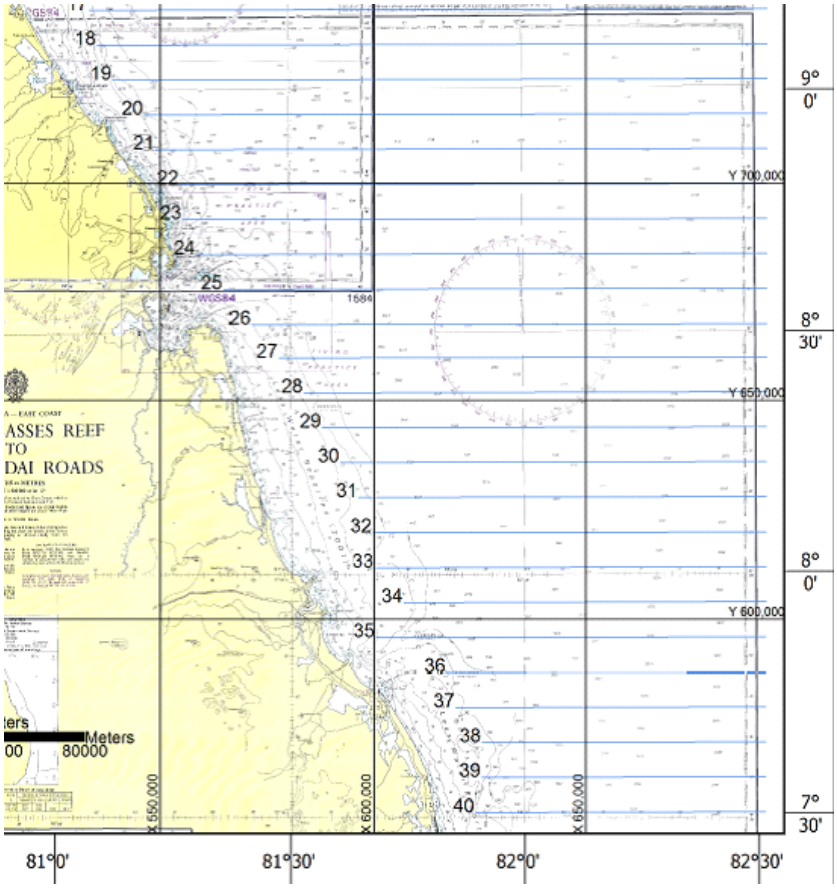


Figure 7.1-6 Coastal Chart "Little Basses Reef to Pulmuddai Roads"

Project 1.3: Bathymetric data acquisition for Coastal Chart "Weligama to Colombo"

60% of the chart was completed at the end of year 2018 and NHO /NARA has intended to complete surveys up to 200m contour .Only 10% of the planned area could completed during the year 2019 since unavailability of RV"Samuddrika" for a considerable time period. Sri Lanka Navy hydrographic unit assure to provide bathymetric data beyond the 200m contour up to the chart limit. Due to the COVID-19 pandemic situation, the gap surveys couldn't carry out as planned within this year.

Project 1.4: Upgrading the published Nautical Charts

The published charts should be maintained to ensure the validity of existing data as the sea bed is subjected to change due to natural phenomena such as Tsunamis, storms or any other extreme weather condition or by other manmade hazard. Any changes of bathymetry are needed to be applied timely. Necessary communication links has been maintained with the relevant authorities, Harbor Master of Sri Lanka Port Authority and Director General of Merchant Shipping Secretariat.

Project 1.5: Data Processing and Cartographic Works

Data processing for the acquired bathymetry (phase I and phase II) of the Nautical chart Trincomalee to Kudremalai Point was completed

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Financial Allocation (Rs) :5,400,000.00

Financial progress (%): 98 Physical Progress (%): 29

7.2 Establishment of Database and online data processing unit for crowd sourced bathymetry parallel with the "Sea Bed 2030" global mapping project of General Bathymetric Chart of the Oceans (GEBCO)/ Nippon foundation

Bathymetric coverage of the sea around our country is very little and need to be done vast area and it needs years and years to fulfil this with the systematic bathymetric surveys. The world contest is very similar and hence the GEBCO Nippon Foundation has started a project called Seabed 2030 and member states of International Hydrographic Organization been invited to collaborate this project covering their own seas from the bathymetry.

The objective of this project is to map the Indian Ocean using crowd sources bathymetry and maintain and updating the data base and disseminate data for marine management, spatial planning and research in marine geology, ecology and oceanography. This will be a continuation project until 2030.

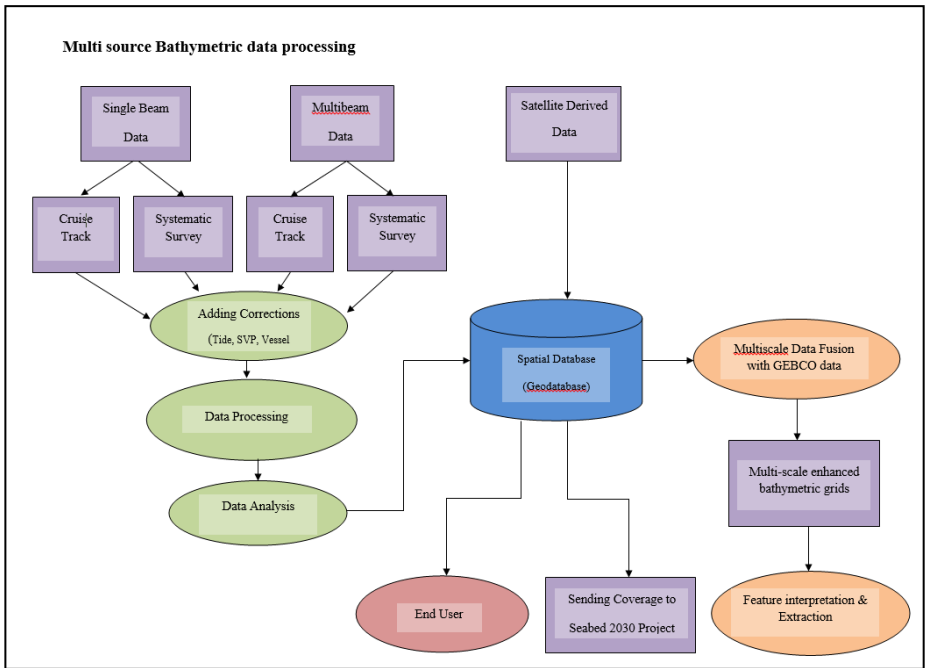


Figure 3:1 Working procedure

Because of the COVID 19 pandemic situation purchasing was delayed of necessary items of infrastructure facilities to establish the structure and networking system as planned for this year. The spatial database interface was generated using ArcGIS platform and model of the surface was created. Further, the requisition has been done from the divisions of NARA to obtain the ship cruises data collected from various sources. The overall progress of the project is 20% for the year 2020.

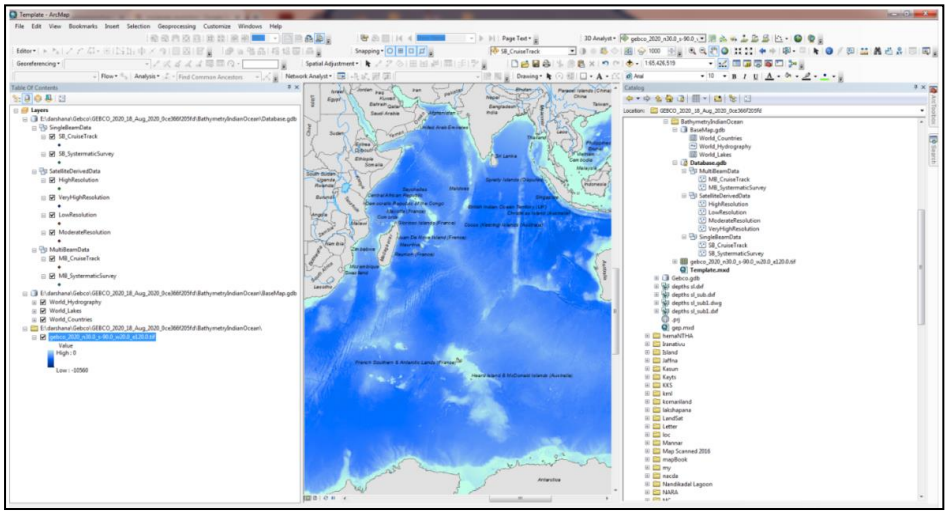


Figure 7.2-1 Spatial Database Interface

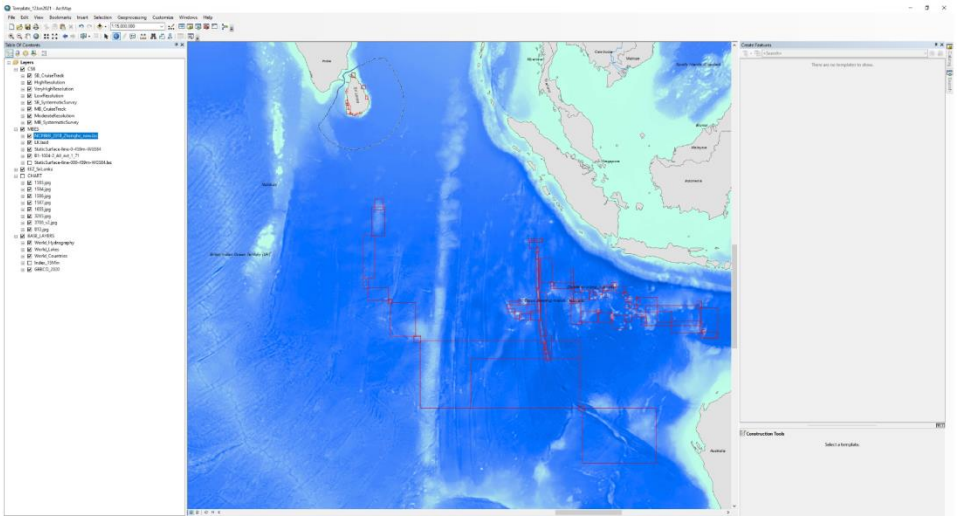


Figure 7.2-2nterface with available data

Financial Allocation (Rs) :100,000.00

Financial progress (%): 95 Physical Progress (%): 20

7.3 An assessment of Tidal asymmetry around the Sri Lankan coastline

Sri Lanka is an island situated in the northern part of the Indian Ocean and is separated by a shallow and narrow Palk Strait. Higher salinity Arabian Sea is located on its western side and the low salinity Bay of Bengal on its eastern side. The continental shelf in Sri Lanka is narrow and is shallower than the average depth of the shelves around the world. It is narrowest around the southern part of Sri Lanka, but it broadens to merge with the Indian continental shelf towards north and northeast. The tide around Sri Lanka is mixed semidiurnal with a spring tidal range of between 0.40 and 0.60 m. The range is less in the northern part of the island. The east coast features different phases from west coast with a rapid change in southeast. The waters around the Island are subjected to seasonal reversals of currents forced by the monsoons.

One of the significant aspect in the tide around the Island is, there exhibits a complete opposite tidal phase difference between Western to South region and East to North region. For an example, when Colombo experiencing high tides, Trincomalee experiencing low tides and vice versa.

This indicates, the tide around Sri Lanka is generated from two different amphidroms in the Indian Ocean. Therefore, the aim of the study identifies these amphidromic points and their influence to the tidal phenomenon around the coast line. A comprehensive regional tidal modelling is expected to carry out encompassing Sri Lanka using existing tidal data. The interaction boundaries of these two amphidroms at the coast line are also expected to be carried out. Several new tidal stations will be set-up to validate the model results. Finally, with these results, it is possible to make a comprehensive study on tidal behaviour around Sri Lanka.

Further, this information is very useful in tidal datum establishment for hydrographic applications such as national charting as well as further densification of the tidal network around Sri Lanka. Further investigations can be carried out regarding the MSL variation and the geoid undulation determination.

Objectives

- To identify the influence to the tidal phenomenon around the coast line caused by the two amphidromic points located in the Indian Ocean.
- To identify the interaction boundaries of these two amphidroms at the coast line along the coast.
- To develop a comprehensive regional tidal model for Sri Lankan coastline.

Data Collection & Analysis

Southeast Amphidrome

Tidal data from Trincomalee, Hambantota and Kirinda tide gauges were analyzed for identifying approximate location of the amphidromic point of Southeast coastline. Additionally 25h tidal observations were carried out at Amaduwa, Patanangala, Kirigalbay, Okanda and Panama which are located along the southeastern coastline. According to the regional tidal model BBay (Bay of Bengal) of Oregon State University (OSU) that has spatial resolution of 1/30°, the amphidromic point for M2 constituent is located between Panama and Kirigalbay (Figure 2:1).

Interpolation of observed 25h and archived tidal data reveals that the amphidromic point of M2 constituent is located near Potthana bay where phase of M2 tidal constituent becomes zero. This location is also confirmed by the interpolation of tidal constituent M2 which was derived from Sea Level Anomalies (SLA) data observed by Satellite altimeters (Figure 2:2 & 2:3).

The amphidrome may also be considered as a time-dependent position of zero tidal range for a complete tidal band. Therefore daily and seasonal movements of amphidromic points needs to be tracked.

Location	**Phase (Degree)**
Trincomalee (1 year data)	65.50
Panama	34.89
Okanda	31.50
Kirigalbay	31.20
Patanangala	293
Amaduwa	320
Kirinda(1 year data)	280
Hambantota(1 month data)	264

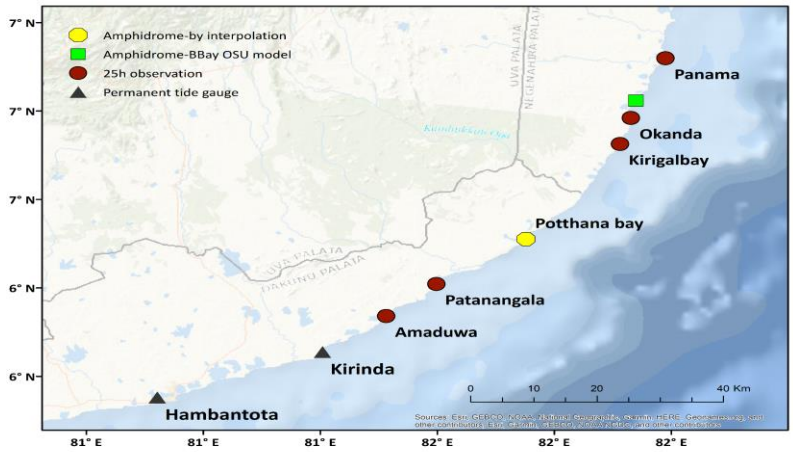


Figure 7.3-1 M2 constituent is located between Panama and Kirigalbay

Table 7.3-1 Phase values of M2 along southeastern coastline

Location	Phase (Degree)
Trincomalee (1 year data)	65.50
Panama	34.89
Okanda	31.50
Kirigalbay	31.20
Patanangala	293
Amaduwa	320
Kirinda (1 year data)	280
Hambantota (1 month data)	264

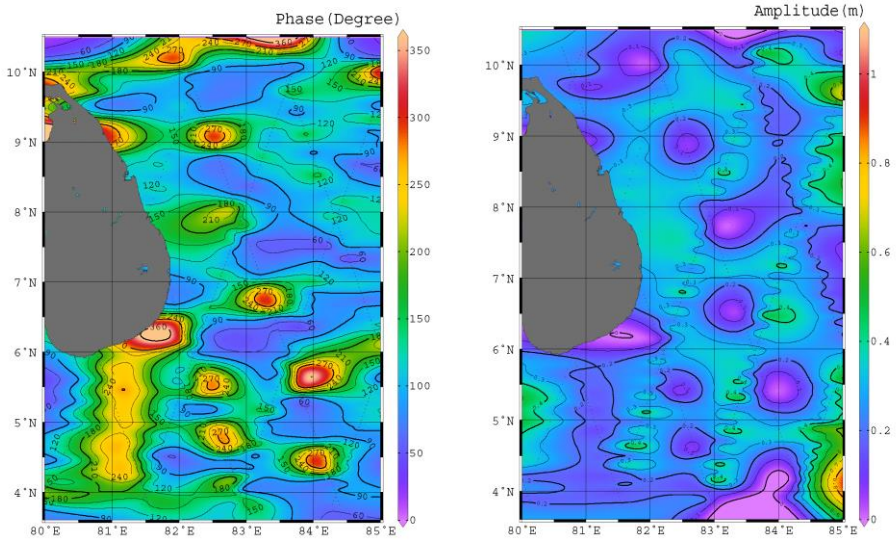


Figure 7.3-2 Interpolation of SLA derived tidal constituent M2-amplitude b) Interpolation of SLA derived tidal constituent M2-phase

Figure 2:2 a)

Northwest Amphidrome

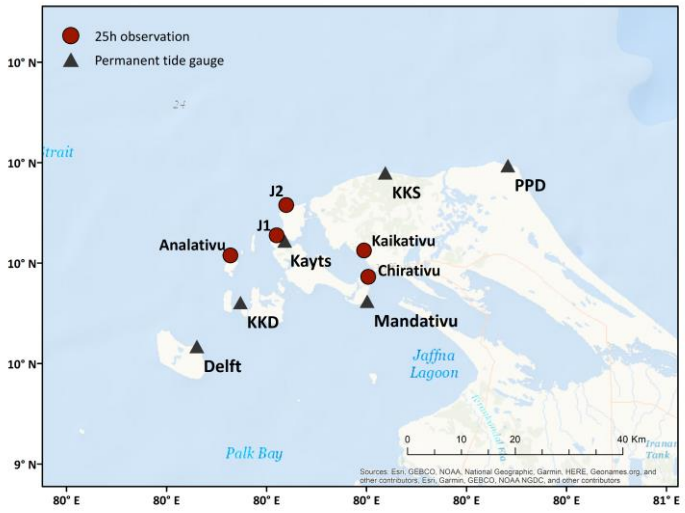
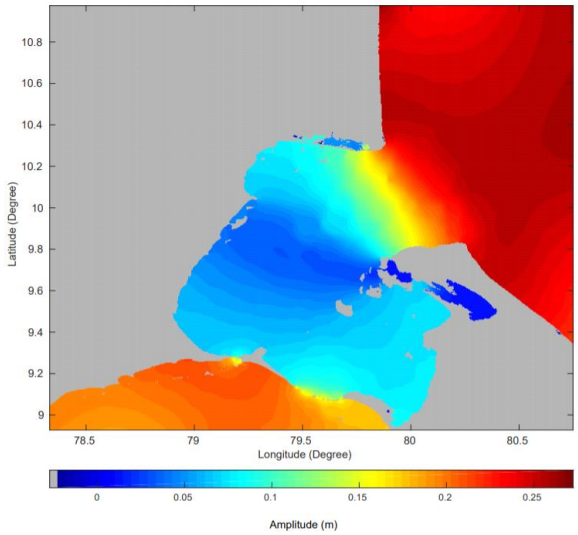


Table 7.3-2 Phase values of M2 of Jaffna archipelago

Location	Phase (Degree)
Point Pedro (1 year data)	78.00
J2	104.00
J1	112.00
Kayts	110
Analativu	239.00
Kurikadduwan	251
Delft	245
Mandativu(1 year data)	254.00
Chirativu	280.00
Kaikativu	346.00

Figure 7.3-3 Installation of tide gauges in Jaffna



A tidal model of 8 major tidal constituents was developed assimilating tide gauge observations for Jaffna archipelago.

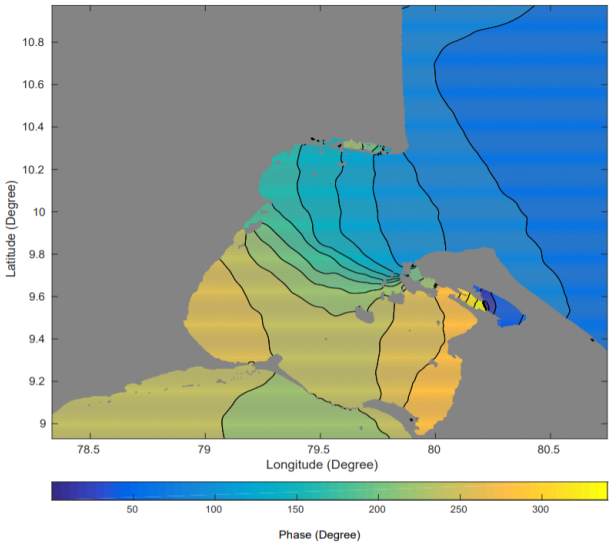


Figure 7.3-4 a) Phase distribution of M2 constituent b) Amplitude variations of M2 constituents

The model simulates the amphidromic point of M2 constituent around Ariyalai Bay (Figure 5a). Other semi-diurnal constituents S2, N2, K2, show the amphidromic system clearly. From diurnal constituents, except Q1, other constituents show the amphidromic system but with a northwest ward shift relative to the semidiurnal constituents.

Further tidal observations needs to be carried out within Ariyalai Bay and Kalundai Bay in order to observe the movements of amphidromic point and validate the tidal model results.

Financial Allocation (Rs) :520,000.00

Financial progress (%): 97 Physical Progress (%): 80

7.4 Investigating Vulnerability of Coastal Erosion in Kalutara

Coastal erosion is becoming a serious environmental issue worldwide due to sea level rise along with climate changes caused by global warming. This study will be focused on Kalutara which is a significant coastal area as the river mouth of Kalu Ganga is located. The sand dune was an important geographical

feature in the area because it protected Kalutara town from sea waves. The final output of the project will contribute to fulfil the existing gap by contributing for decision making relevant to coastal environmental protection and policy planning. The literature review part is completed and due to the COVID 19 pandemic of the country, the process of the purchasing of satellite images and field work were hindered on time and couldn't continue the project within the year 2020. Further, purchasing of satellite images is in progress. Therefore, the freely downloaded satellite images and Google earth images were used for extraction of coastlines from 2005 to 2017. The digitized outlines were opened in ArcGIS to identify the spatial variation. Seasonal variations of the sandbar were observed for the period of 2005-2017. This is mainly happening during the southwest monsoon period prevailing from May to September. Also both the erosion and accretion have to be measured in GIS environment in order to get the relationship with monsoonal periods.

Figure 7.4-1 Sandbar in 2005 (blue), 2010 (orange) and 2015 (red)

Financial Allocation (Rs) : 20,000.00

Financial progress (%): 51 Physical Progress (%): 80

8 Socio Economic and Marketing Division

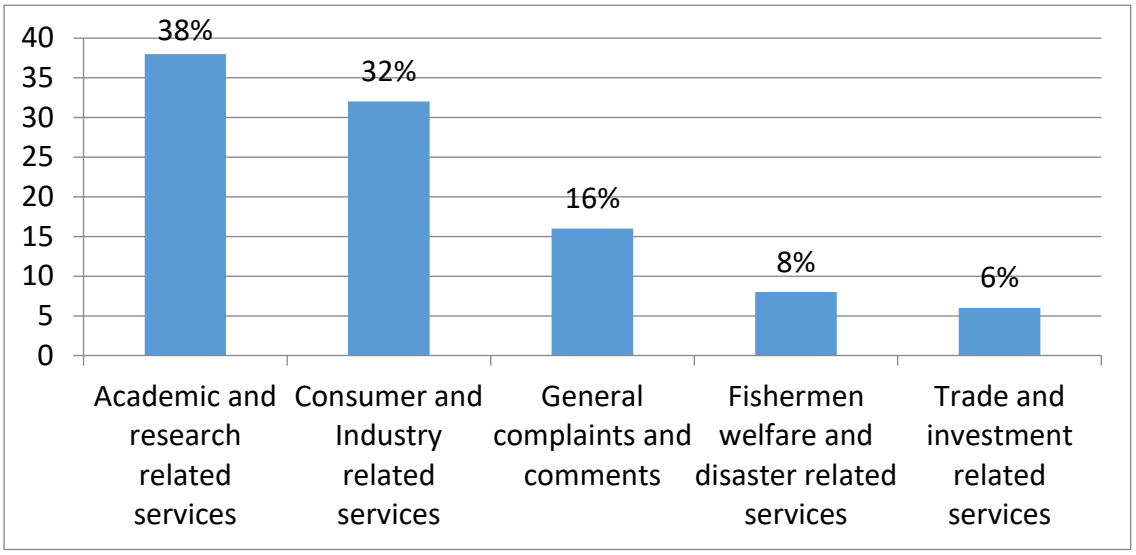
8.1 The fisheries information centre (FIC) of NARA

Socio-economic Division maintains the Fisheries Information Center (FIC) to provide necessary information for stakeholders and other interested parties of Sri Lankan fisheries industry. The end of the year 2020, a total number of 144 queries were received through the hot line 07 10 10 10 10 of fisheries information Centre from different respondents. This is relatively low number of inquiries when compared to last year, and it is mainly because of Covid-19 pandemic restricting fishing operation all around the country during 2020. All the queries are categorized in to five groups. Numbers of queries and the percentages under each information criteria are given bellow table.

Numbers of queries and the percentages under each information criteria

Information criterion	Number of calls received	Percentage
Academic and Research Related Services	55	38
Consumer and Industry related Services	46	32
General Complains and Comments	23	16
Fisherman Welfare and Disasters Related Services	12	8
Trade and Investment Related Services	9	6
Total	145	100%

Number of calls received



All queries received were successfully solved out with the assistant of NARA scientists, officials of Ministry of Fisheries and Aquatic Resources Development (MFARD), Department of Fisheries and Aquatic Resources (DFAR), National Aquaculture Development Authority (NAQDA) and other relevant officers from the governmental and non-governmental sectors. To promote the information center among stakeholders of fisheries sector more than 10 banners were displayed in the fisheries harbors and 500 of leaflets were distributed in harbors, landing site, fisheries inspectors' offices, and other government and non-government office premises which are located all-around the costal line of Sri Lanka.

Financial Allocation (Rs) : 330,000.00

Financial progress (%): 100 Physical Progress (%): 90

8.2 An analysis of Gender Role in Small Scale coastal Fisheries (SSF) in Sri Lanka (SL)

The contribution of Small Scale Fisheries sector (SSF) in Sri Lanka is recognized as major factor for sustaining livelihoods in fisheries industry and it is diverse with gender divisions of labour that men and women are engaged in distinct and complementary activities. Considering the significance of promoting gender division of labour to enhance the socio-economic condition of fishermen and fisherwomen, this study focused on the gender roles of three aspects of SSF: active fishing, dry fish processing and marketing. This study was conducted in Negombo fisheries district of Western Province and Chilaw fisheries district of North Western Province of Sri Lanka. A socio-economic survey was conducted using semi- structured questionnaire from 60 fishing households based on the non-probability, convenience sampling method. Data was obtained from both men and women in the selected families. The sample was comprised of 40 active fishing households (66.7%), 12 dry fish processing households (20%) and 8 from the fishing households who engaged in fish marketing activities (13.3%) in SSF. Interviews and observation methods were used to collect further information. Field data was analyzed using SPSS statistical package and Harvard Analytical Framework was used for gender role analysis.

According to the results of the study, a majority of the fishermen in Negombo (40%) and Chilaw (43.3%) was in the range of 41-50 years. The majority of the fisherwomen in Negombo (43.3%) were in the range of 31-40 while the majority of fisherwomen in Chilaw (30%) were in the 41-50 age categories. The mean value of monthly income of fishermen was varied among the three aspects of active fishing, dry fish processing and fish marketing and it was in the range of Rs. 40000-60000. Out of the sample, 26.7% of fishermen in Negombo were engaged in secondary occupations such as driving, hiring works, lagoon fishery, agriculture and net mending while 10% of fishermen in Chilaw were engaged in secondary occupations. The majority of fisherwomen in Chilaw (40%) involve with the dry fish processing activities and the average monthly income was Rs. 18500. Sewing clothes and preparing food items were key secondary occupations of fisherwomen (13.4%) and they earned a sum of Rs. 5000 average monthly income and contributed to their families. Though seagoing fishing can be seen as a male dominated activity, 26.7% and 40% fisherwomen from Chilaw and Negombo respectively supported for their fishing activities as unpaid family workers. Except seagoing fishing and aquaculture, fisherwomen engage in pre-harvest and post-harvest activities include net clearing, net loading, net mending, repairing nets, sorting fish, dry fish making and fish selling. Study results revealed that fisherwomen played a vital role in productive activities, household and community activities. More than 80% of contribution was provided by the fisherwomen in household management.

The fishermen and fisherwomen in SSF in Sri Lanka face social, economic, institutional and environmental barriers. Reduce the fish harvest, damage to fishing nets, high cost of fuel and high cost of fishing gears are major issues faced by fishermen while fisherwomen face many constraints in gender empowerment such as lack of recognition for women's work and contribution, lack of participation for governance and sustainable resource management, gender discrimination in wage labour, fewer opportunity for economic participation due to household chores and social and cultural pressures. Both fishermen and fisherwomen face common issues in gender empowerment such as price fluctuations and marketing problems, poor coordination of fishing societies, lack of infrastructure facilities and lack of technology. It is recommended to concern gender roles and issues in to policies/planning projects in the fisheries sector to empower both gender for the well-being and economic prosperity of SSF in Sri Lanka.

Financial Allocation (Rs) : 200,000.00

Financial progress (%): 95 Physical Progress (%): 98

8.3 Bio-Economic analysis of declared Marine Protected Areas (MPAs) in Sri Lanka

The project area was Kayankerni reef that was declared as a natural sanctuary in 2019 and the major objective of the study is to identify the Soco-economic benefits of MPAs. It was found that the fishing is major economic activity around the sanctuary and tourism is immerging economic activity around the Kayankerni sanctuary. The sanctuary belongs to the Vakarai South Fisheries Inspector division and major fish landing sites are Kayankerni and Mankerni. In addition to that fishers who live closed to Wakarai, Senkadamunai are also fishing in the area around the sanctuary.

As a result of the reef is located close to the beach (around 3 Km), fishers who use non mechanized boats (NTRB) fishing closed to the sanctuary. While the fisher who use OFRP boats are fishing away from the reef (around 15km-20km). The day income is highly fluctuated and the average profit of the one day fishing is range from Rs: 1000.00 to Rs: 5000.00. Fishers who use OFRO boats, do not clearly identify extra benefits getting from reef for their harvest. However, fishers who are fishing from NTRB have cleared identify the benefit of reef for their fishery, especially during the off season. Beach de-mer fishers collect the beach de-mer, beyond the reef. Around 10 fishers in Kayankerni engage in beach de mer collation and average income of the day per fishers is 5000.00.

Boat hiring for the tourists arrange by the local fishers who are located at the fish landing site (Kankerni) and the average cost of the boat hire for visiting reef e is about Rs 3500.00. However, the fee of the boat hire varies according the time spent at the reef. For n instant, if tourists stay at coral reef around half a day, the boat hire can be around Rs 7500.00. As fishers are engaging for boat hiring for the tourist, they have increased their income.

It was identified some threaten to the reef from the fishing activities as well as tourism. According to the fishers, bottom set net and the fishing from dynamite are the major threaten for the reef, while unawareness of the local tourists for the importance of the reef has badly influence for damaging reef. Weak monitoring and coordination among stockholders of the reef users is also badly influence for the protection of the reef.

Financial Allocation (Rs) : 700,000.00

Financial progress (%): 97 Physical Progress (%): 95

8.4 Value Chain Analysis and its Performance of Herring and Sardinella Fisheries in Sri Lanka

In the coastal fisheries in Sri Lanka, *Amblygastersirm* (Herring/ Hurulla) is the dominant species followed by *Sardinella gibbosa*(Salaya) and *Sardinella albella* (Sudaya) with the relative contribution of 21.96%, 11.65% and 9.76%, respectively (BOBLEM, 2015). The objectives of the study were to analyse and map the present value chains of Herring and Sardinella fisheries and to identify gaps and ways to develop existing value chains on the concept of value chain development. The study area was Negombo, Chilaw and Puttlam fisheries districts of West coast, selected based on the high availability of Herring and Sardinella fish. Sample of 65 value chain participants (50 fishermen and 15 intermediaries) were selected using convenience sampling method and interviewed using pre tested semi structured questionnaire. The data were analyzed using SPSS ver. 22 and Ms Excel as relevant. Analysis was done by a few steps. First, the key economic agents, their roles and main functions were identified. Basic configuration of marketing channels was mapped and flow of fish from one node to

other along the value chain was simply calculated in percentage. Three marketing performance indices were calculated namely; marketing efficiency index ((Acharya and Agarwal, 2007), price spread (Narayanakumar and Sathiadhas, 2006) and fishermen's share in consumer's rupee (Aswathy, 2014) and the efficiencies of identified marketing channels were compared using calculated performance indices.

The results revealed that both Herring and Sardinella fisheries have the same structure of value chains which were aligned across five main stages; production, assembling, wholesaling, retailing and consumption. Five major value chains were observed (Table 01) and further analyses were done for channel 01, 02 and 03 because a vast quantity of Herring moved through those channels.

Table 8.4-1 Different marketing channels of Herring and Sardinella fisheries in West-coast of Sri Lanka

Channel	Player 1	Player 2	Player 3	Player 4	
1	Fishermen	Assembler	Retailer	Consumer	
2	Fishermen	Assembler	Consumer		
3	Fishermen	Retailers	Consumer		
4	Fishermen	Consumer			
5	Fishermen	Assembler	Wholesaler	Retailers	Consumer

The average annual net profit of a Herring fishing unit was found as LKR 406 416 while it was LKR 283 500 for Sardinella fishing unit. The results verified that both Herring and Sardinella fishery in the West coast is still a profitable commercial fishing activity. A market can be regarded as efficient, when the price spread is lower and share to the fishermen and marketing efficiency index are higher (Narayanakumar and Sathiadhas, 2005, Shephered Geoffrey, 1972). Summary of price spread, fishermen’s share in consumer’s rupee and marketing efficiencies of marketing channel 01, 02 and 03 were showed in Table 01. Results confirmed that the most efficient marketing channel for both Herring and Sardinella fisheries in the West coast of Sri Lanka is channel 02 in which fish flows to the end consumer through the assembler.

Table 8.4-2 Summary of price spread, fishermen’s share in consumer’s rupee and marketing efficiencies of marketing channel 01, 02 and 03.

Fishery	Particulars	Marketing channel 01			Marketing channel 02	Marketing channel 03		
		Motor bicycle vendor sub chain	Bicycle vendor sub chain	Roadside vendor sub chain	Assembler as the intermediate	Motor bicycle vendor sub chain	Bicycle vendor sub chain	Roadside vendor sub chain
Herring	Price spread (LKR/Kg)	205	205	205	80	180	180	165
	Fishermen's share in	54.44	54.44	56.32	75.53	60	60	62.06

	consumer's rupee (%)							
	Marketing efficiency index	1.19	1.19	1.28	3.06	1.5	1.5	1.63
Sardinella	Price spread (LKR/Kg)	190	190	160	60	180	180	105
	Fishermen's share in consumer's rupee (%)	45.71	45.71	50	75.53	48.57	48.57	52.12
	Marketing efficiency index	0.84	0.84	1	2.66	0.94	0.94	1.13

The following recommendations can be given based on the finding of the study; to establish a proper market information network and provide access to all value chain actors, to augment the government intervention in development of infrastructure facilities for storage and processing of Herring and Sardinella fish and to ease the procedure of institutional finance to protect the fishermen from the clutches of money lenders and other intermediaries, particularly the assembler.

Financial Allocation (Rs) : 400,000.00

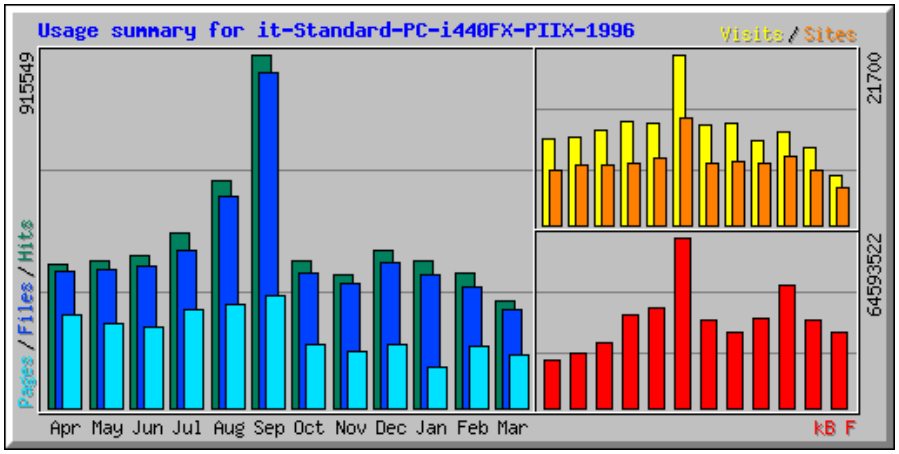
Financial progress (%): 100 Physical Progress (%): 100

9 Monitoring and Evaluation Division

9.1 Internet services and online information system

Responsible Officer : A.B.A.K. Gunaratne

Main objective of the project is to disseminate the information via World Wide Web and to provide other internet services for scientific staff of NARA and its stakeholder with a view of facilitating information sharing. Modifications were carried out to the website 98 web pages were added to the site. Average visit per day to the web site was nearly 435 and observed the highest visit counts, 19433 on June 2019.



Summary by Month

Month	Daily Avg				Monthly Totals					
	Hits	Files	Pages	Visits	Sites	kB F	Visits	Pages	Files	Hits
Mar 2021	12011	11063	6067	274	4839	28401905	6314	139551	254467	276258
Feb 2021	12504	11257	5717	350	6924	33362979	9822	160087	315210	350113
Jan 2021	12343	11190	3388	385	8725	46787745	11955	105051	346912	382649
Dec 2020	13136	12148	5315	345	7941	34235815	10716	164786	376617	407220
Nov 2020	11447	10770	4953	430	8028	28602231	12928	148593	323111	343420
Oct 2020	12276	11316	5368	411	7963	33316988	12767	166423	350819	380584
Sep 2020	30518	28904	9672	723	13509	64593522	21700	290169	867126	915549
Aug 2020	18960	17651	8612	417	8508	38130063	12927	266991	547190	587765
Jul 2020	14576	13237	8243	423	7950	35450905	13138	255543	410369	451864
Jun 2020	13206	12245	7024	400	7721	24747421	12004	210745	367369	396186
May 2020	12323	11570	6992	362	7646	21020248	11250	216774	358685	382029
Apr 2020	12381	11841	8078	366	6885	18411645	11008	242357	355241	371443
Totals						**407061467**	**146529**	**2367070**	**4873116**	**5245080**

Staff engaged with PC assembling and day to day computer troubleshooting and repairs,network repairs with Network expansion work including network cabling and installing network accessories

Inform Database that used to evaluate research projects of the institutions engaged in CARP network, was submitted to CARP. Expected target was achieved during the period. Information on human resource and financial statement was submitted to the National Science Foundation and NASTEC for the Research and Experimental Survey 2019.

Financial Allocation (Rs) : 2,700,000.00

Financial progress (%): 100 Physical Progress (%): 100

9.2 Assessments and monitoring research projects

Responsible Officer : A.B.A.K. Gunaratne

Budget : 0.75 million

Project performance report and annual report for the year 2019 were produced. Monthly and quarterly progress report to Presidential Secretariat, Treasury and Ministry were submitted

Quarterly progress review meetings were conducted within the institute and required adjustments and advices were delivered by the Deputy Director General in order to solve the issues aroused.

Financial Allocation (Rs) : 120,000.00

Financial progress (%): 98 Physical Progress (%): 100

9.3 Annual Scientific Sessions

Responsible Officer : A.B.A.K. Gunaratne/Mr. M Maheepala

Annual Scientific Session 2020 was held as a webinar due Covid outbreak. The session theme was "Technologies innovations for fisheries and aquaculture development" and sessions were accommodated on a wide range of themes, including Fisheries and Aquaculture, Aquatic Biotechnology and Animal Health, Coastal and Marine Habitat Enhancement, Oceanography and Hydrography, Socio-Economics and Marketing, Aquatic Post Harvest Technology, Coastal and Marine Pollution, Conservation and Management of Aquatic Environment, Climate Change and its Impacts. As the leading research organization on the living and non-living aquatic resource sector, NARA contributes in knowledge sharing by conducting high quality research of national and international standards.

The Inauguration ceremony was graced by Prof. N. Nawarthnarajh, Chairman, NARA. The key note address was made by Prof. Alen Deidu, Director of the International Ocean Institute University of Malta,

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Financial Allocation (Rs) : 5,000.00

Financial progress (%): 98 Physical Progress (%): 100

9.5.Collection Development

Strengthened the Library resources by purchasing, donations, exchanges and electronic downloads according to the requests of the scientists of NARA. Also, collected information relevant to NARA.

Purchases:

06 Journals were requested for the year 2020, out of them only 01 was subscribed & 01 was renewed.

16 book titles were requested, out of them only 12 were selected and 01 was not supply.

Renewed payment for purchasing AGORA database and National Geography for this year.

Purchase, Donation & Exchange:

Received 14 Books, 28 journals, 14 Travel Reports, 54 Research articles, 01 thesis, 15 NARA reports & 188 Newspaper article.

Financial Allocation (Rs) : 610,000.00

Financial progress (%): 100 Physical Progress (%): 90

9.6 Maintenance of Library Management System

Library Web Catalogue

Updated library web site (http://www.nara.ac.lk/?page_id=3373) along with a web catalogue (www.lib.nara.ac.lk) and e repository (www.erepository.nara.ac.lk)

Financial Allocation (Rs) : 470,000.00

Financial progress (%): 99 Physical Progress (%): 95

9.7 Implementing Library Management System

The resource acquired, were catalogued and classified manually and also entered to the Open Public Access Catalogue (OPAC) and accessible not only to the NARA but also to the public. Digital collection was also updated regularly.

Library resource referral service was accessible to the scholars using OPAC. Edited 1,100 data with contents for the Library Management System (LMS) and 11 for the repository collection.

Reference Services

In order to retrieve from e-Journal articles, Postgraduate theses, Research reports, Research articles and Newspaper clippings databases were updated electronically and were compiled databases using KOHA LMS and Digitization project. Summary of data entered to the digitization project as given below.

Digital Data Collection

Name of the Collection	Quantity of Data
NARA Publications	1018
Postgraduate Theses	77
Research Reports	116
Research Papers	151
Newspaper Clippings	170
Administrative Reports	45
Acts	03
Proceedings	54

Collected information for literature surveys for the following titles –

- Marine mammals
- Climate change
- Corals

- Fish disease
- Shrimp disease

Replied for the information requests made by users over the phone and also via email.

3.2 Under National Digitization Project, Electronic Article database was updated by entering research paper data.

3.3 Library has provided services for the Scientists, Researchers, Postgraduates and Undergraduates who arrived from different institutions and universities. The Number of users visited was 298 nos. 187 books were lend under library circular system.

3.4 Document Delivery Service - Library has joined for the British Council Membership programme and Under selective dissemination of Information service provided 298 nos. research reports for Nara Scientists from co-operative libraries.

3.5 Library has provided photocopy and document scanned services - the total amount received through photo-copying during the year was Rs. 3821.00 and 400 Pages photocopied and 68 documents scanned for free of charge for internal readers.

Financial Allocation (Rs) : 200,000.00

Financial progress (%): 88 Physical Progress (%): 80

10 Technology Transfer Division

9.4 Stakeholder Consultation Meeting

The consultation meeting was conducted at NAQDA resource center, Kalawewa parallel with induction training for newly recruited Scientists. Funds shared with local Training component hence financial progress is 28 % and the meeting was completed with limited number of stakeholders due to covid pandemic situation

Financial progress (%): 28 Physical Progress (%): 80

9.8 Extension Services

Officer Responsible: D.V.S.P .Bandara, G.J .Ganegama Arachchi

Participation at educational exhibition

Extension Unit participated as exhibitors representing NARA at education exhibition called " IMPULZ 20", organized by Hanwella Rajasinghe National School from Jan 13-18, 2020. NARA-Exhibition stall displayed different ornamental fish species and fish and seaweed based value added food products. Scientific and technical knowledge on aquatic resources were disseminated using video programs, Face book Updates on R&D work and leaflets etc with participation of resource personnel from all Technical Divisions including Marine Biological Resources Development, Inland Aquatic Resources Division, Post Harvest Technology, Fishing Technology, Environmental Studies, Oceanography and Marine Science and National Hydrographic Office.

A video program was produced on production of fish meal at commercial level in aFish Meal Plant including all steps from collecting fish wastes as raw materials for the feed to the finished fish feed material which are ready for sale.

Media coverage was arranged for the inauguration session of fish feed plant at Ja-Ela on February 05, 2020.

Provide tailor-made trainings for Navy personnel and other stakeholders.

NARA facebook was updated: Forty two (42) technical notes have been posted.

Editing the booklet Titled 'Lagoon crabs in Sri Lanka' prepared by Dr. Mrs. M. G. I. S. Parakrama

Four number of one-day training programs about R&D works and services relevant to the aquatic resources, were conducted for four groups of Navy personnel in February, 2020.

Outcome: Learned public about sustainable utilization and management of aquatic resources

Financial Allocation (Rs) : 2,300,000.00

Financial progress (%): 100 Physical Progress (%): 70

9.9 Awareness through media - build awareness on the most threatened endemic freshwater fishes of Sri Lanka and restoration of most vulnerable ecosystems

Officer Responsible: R. R. A. Ramani Shirantha, D. V. S .P .Bandara, G. J .Ganegama Arachchi

Activities:

As a measure for the conservation of *Malpulutta kretsiri, Pethia cumingii Dawkinsia srilankensis, Labeo fisheri, Systomus matenstyni* and *Danio pathirana* in natural habitats it selves, it was planned to install display- boards on these threatened endemic fish species at four selected locations where these fish species are found naturally in Kegalle district (Yatiyanthota, Kegalle, deraniyagala, Mawanella and Rambukkana) with permission of Department of wild life and relevant Divisional Secretariat in Kegalle District. Preparation of four fish- display boards has been completed. Three Display Boards were established at selected sites in Kegalle district: Kithulgala town, Meeoya Bridge, and Kithulagala bathing place near water spring.

Outcome: Creation of awareness about threatened endemic fish species among stakeholders in Sri Lanka.

Financial Allocation (Rs) : 530,000.00

Financial progress (%): 99 Physical Progress (%): 60

9.10 Aqua club educational programme

Officer Responsible: D. V. S. P. Bandara, Ms. J. M. N. Jayasundara and Ms. S. H. U. Chathurani (Kadolkelle Regional Center), G. J .Ganegama Arachchi

This project is implemented with approval and supervision of Ministry of Education. The aim of this project was to enhance knowledge on sustainable utilization and management of aquatic resources among school children.

Activities:

Four workshops have been conducted at following schools with participation of Scientists from NARA as resource personnel.
Ambalangoda Dharmashoka National School
Modera Ananada Maha Vidyalaya
Dehiwala Presbritriyan Vidyalaya
Chilaw Ananda National School
Establishment of mangrove plant nursery in NARA regional Center at Kadolkele was included in the revised work plan (July-December, 2020) which was made considering the Covid Pandemic in 2020. Aim of this activity was to create awareness about mangrove plants among school children and mangrove saplings prepared in 2020 will be planted in selected locations with participation of school children in 2021.

Nypa fruticans (mangrove palm, 'ging pol') is threatened mangrove plant in Sri Lanka mainly due to destruction of natural habitants by unplanned anthropogenic activities and however, it has been shown as economically valuable mangrove plant in other countries. Sap of *Nypa fruticans* inflorescence is suggested for bioethanol industry and various parts of other parts of this plant including leaves, and young shoots are utilized at cottage level industries. Mangrove palm is currently not utilized for any commercial purposes in Sri Lanka.

Two field visits were made to observe and gather information about current status distribution of *Nypa fruticans* at Kammala village alone with the river bank of Hamilton canal to from Negombo lagoon to Maha-Oya River.

Current threaten factors/ issues regarding the failures of earlier projects on the restoration of *Nypa fruticans*:

Sand mining has negatively influenced on the growth of the plant. It has accelerated the root out of the plant along with the force created by water current.

Boat riding with elevated speed for tourism and other fishery activities has accelerated of root out of small and mature *Nypa fruticans* plants

During field observations, it was also identified that the stilt roots of *Rhizophora apiculata* and *Rhizophora mucronata* have provided the protection of water currents and support for stabilization on the substrate by minimizing the chances of rooting out.

Secondary plants with economic value:

Communications with resident communities in the area during field visits it was identified that *Nypa fruticans* can be cultivated in suitable environments together with other secondary plants such Alovera, *Acrostichum aureum and Bacopa monnieri* which has potential for source of income generation for the communities because it takes about 4-5 years to bear *Nypa fruticans* plants which can be utilized for sap based industries.

Seeds of *Nypa fruticans* were collected for the utilization of a nursery at Kammala village (Latitude: 7^{o} 17’ 55.96”; Longitude : 79^{o} 51’ 1.82”). Two nurseries were prepared by setting 350 *Nypa* seeds which were collected from Gin-Oya area in Kadolkale Regional Research Center (KRRC) in Negombo.

Video recordings were obtained for production of video documentary on *Nypa fruticans*

Outcome: Enhancement the knowledge on sustainable utilization mangrove plants among school children

Targets could not be achieveddu to covid pandemic situations

Financial Allocation (Rs) : 230,000.00

Financial progress (%): 96 Physical Progress (%): 10